THE UNIVERSITY OF ALBERTA

THE FUTURE OF AGGREGATE USAGE IN CENTRAL ALBERTA

by

© DONALD DAVID PRIDY

A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES AND RESEARCH

IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE

OF MASTER OF BUSINESS ADMINISTRATION

DEPARTMENT OF BUSINESS ADMINISTRATION AND COMMERCE

EDMONTON, ALBERTA

SPRING, 1980

This thesis is dedicated to my wife Charlotte. To me, her name is synonomous with patience and understanding.

ABSTRACT

The major objective of this study was to formulate a means of forecasting the demand for sand and gravel in Edmonton and within a 70 mile radius of the city during the thirty year period, 1978 to 2007, and to compare those requirements with potential supplies of natural aggregate building materials. An analysis of supply conditions was conducted and required consideration of elasticities of aggregate demand and supply including the effects of current land use policies on available aggregate reserves.

Previous studies of this type were surveyed and a methodology developed through which a forecast was made of total future demand for construction in the Province of Alberta. The key predictive variable was the number of household units in the province. Predictions of future household formation were used to forecast provincial construction spending; an allocation to the study area was then based upon relative population and growth rates. Regional spending was then converted into estimates of aggregate consumption using historical data relating the proportion of spending in different construction sectors to the rate of aggregate usage per dollar of construction spending.

The conclusion derived from the study was that the most probable aggregate usage to 2007 will consume only about 7 percent of the engineering reserves existing within

the study area. However, a more significant proportion, up to 20 percent, of rarer, quality materials will be depleted. A comparison of the location of aggregate reserves and the land use regulations governing those locations found that 8.5 percent of current reserves have been removed from access because of land use or zoning conflicts. The net result was that, if no further sterilization of reserves occurs due to urbanization of aggregate containing lands, by 2007, 15 percent of all aggregate reserves in the study area will be depleted and 25 percent of quality materials will have been used. However, it should be stressed that as the real price of aggregate increases, economic reserves of aggregate will increase as well since it then becomes feasible to transport aggregate for greater distances from locations now outside the defined study area.

The relative consumption of aggregates was found to be rather insensitive to alternative estimates of Year 2007 population in the study area. The range between the maximum and minimum in those population estimates was 25 percent of the most probable final area population of 1,240,000 (the lower of the two estimates).

Recommendations are that aggregate reserves be enumerated and that conservation practices be established to prevent excessive increases in aggregate prices and environmental conflicts. In addition, a careful assessment should be made of the effect that setting aside land for future aggregate production will have on aggregate prices

and reserves before such mineral resource reserves are established.

ACKNOWLEDGEMENTS

The author gratefully acknowledges the contributions from the many people who made this thesis possible. I am particularly indebted to Dr. E.J. Chambers for the time and consideration he has accorded me. I am further indebted to both the City of Edmonton and the Government of Alberta who made major contributions during the data gathering process.

TABLE OF CONTENTS

TABLE OF CONTENTS continued

LIST OF TABLES

LIST OF FIGURES

TABLE OF NOMENCLATURE

Aggregate - "Any of several hard, inert, construction materials (such as sand, gravel, shells, slag, crushed stone, or other mineral material), or combinations thereof, used for mixing in various sized fragments with a cementing or bituminous material to form concrete, mortar, plaster, etc., or used alone as in railroad ballast or in various manufacturing processes (such as fluxing)."[1]

Backfill - Aggregate material or soil used to replace material excavated to facilitate the installation or repair of engineering constructions.

Clay - Very fine mineral particles of soil or earth, classified by engineers as being smaller than 0.075 millimetres in size and acceptable only in limited amounts in combination with usable aggregates.

Concrete Aggregates - A class of aggregates generally considered to be of high quality because they meet the requirement that they be essentially free of coal, excess clay and silt, and other organic or otherwise deleterious matter that would detract from use in portland cement concrete.

Cumulative Usage - In the context of this report, the sum of aggregate consumed during each year of the time period under consideration up to and including the final year of the time period.

Deleterious Matter - Undesired mineral or organic matter which, in the case of aggregates, interferes with the intended use of a material.

Economic Reserves - Quantities of sand and gravel which can be economically produced at current price levels.

Engineering Reserves - All sand and gravel, within the region under consideration, that can be produced by conventional open-pit production techniques.

E-Phase Resistivity Survey - A geological exploration technique which utilizes measurements made on the behavior of electrical fields directed into the ground at a site to determine the nature of sub-surface layers of materials.

Fluvial Material - Material produced, sorted and distributed by the washing action of streams and rivers.

Glacial Material - Aggregate materials derived from surface materials collected up, crushed, sorted or washed by the build up, movement and melting of glaciers known to have covered this part of North America during certain past time periods, produced by some idiosyncrasy of the Earth's climate.

Glaciation - Scraping, crushing and rearrangement of the Earth's surface during the formation and movement of glaciers.

Gravel - Aggregate material exceeding 4.75 millimetres in diameter.

High Quality Materials - Aggregate materials such as concrete aggregates which are in demand for their desirable properties and the fact that they can be utilized with a minimum of further processing.

Kame and Kame Morraines - Mounds or ridges of material, commonly sand and gravel, deposited by streams running under the surface of a glacier and deposited as a delta parallel to the edge of the glacier.

Natural Aggregates - Aggregates mined or quarried from land surface sites and not originating as a waste or by-product from industrial, commercial or domestic activities.

Outwash Plains and Deltas - Stratified, loose rock fragments originating from deposits within glacial ice and deposited at locations away from the body of ice by meltwater streams.

Overburden - Soil covering an underground aggregate deposit that must be removed to gain access to the deposit for extractive activities.

Planning Horizon - The future time period for which plans are specifically formulated.

Porosity - The degree of occurrence of pores or interstices in a material, such as an aggregate, to which foreign liquids or solids may gain access.

Postglacial - Refers to activities or aggregate deposition which took place at a later date than the dispersal of the continental glaciers in a region.

Preglacial Rivers - Rivers which existed before the onset of glaciation and normally were changed in location, elevation and character, if not eliminated entirely, by glaciation.

Protected Reserves - The portion of engineering reserves which is protected, from loss through urbanization of aggregate bearing lands, by land use regulations.

Recent Deposits - Fluvial and lake related deposits formed after the last period of glaciation.

Resorted - As applied to aggregates, materials which were moved from their original location of deposition and deposited elsewhere probably in a less pure form. Often used to refer to glacial modification of preglacial deposits.

Sand - Aggregate material with particle size diameters in the range of from 0.075 to 4.75 millimetres.

Silt - Soil made up of particles less than 0.05 millimetres in diameter.

Soundness - Describes the ability of a particle of aggregate to resist deterioration caused by chemical or physical action.

Spillways - Meltwater channels which conducted water away from an adjacent body of water or source such as glacial meltwater. Often, but not always, the location of aggregates deposited by the meltwater.

Stratas - Layers of rock, granular material or soil deposits that go together to form the land surface structure at a location.

Surficial Deposits - Deposits of rock, granular material, minerals and soil located at or near the surface of the ground.

Surficial Geology - The science of mapping, predicting, interpreting and determining the surficial deposits to be found at a location.

Tenor - Term used to describe the quality or relative utility of an aggregate deposit in its as-found condition.

Thalwegs - Buried valleys that once were water courses for rivers which existed before glaciation buried the valleys changing the postglacial drainage pattern of the area.

CHAPTER I

INTRODUCTION

Sand and gravel is used in the construction of roads, streets, railways and other transportation facilities, as backfill, as a raw material in glass manufacturing and, in fact, in any application which requires concrete (surfacings, foundations, supporting members, concrete blocks and pipes) or utilizes asphaltic surfacings.

Although basically inexpensive, the vast quantities of sand and gravel used each year dictate that large reserves be available in close proximity to urban centers to ensure adequate, reasonably priced supplies.

Aggregate costs account for 20 to 30 percent of the cost of building pavements, dams, major structures and public works. The building of a house requires 300 tons of material while a highway can consume 60,000 tons in one mile's construction. The weight and volume of the sand and

gravel materials involved means that it is costly to transport supplies very far. Current transport charges in the Edmonton region range up to 14 cents per ton mile, or from 30 to 90 percent of the in situ value of the aggregate.

In recent years increasing attention has focused on the supplies of aggregate available to major cities. To date, studies have been conducted into the aggregate wealth in the areas surrounding Toronto and Winnipeg while less formal assessments have been carried out elsewhere in Canada.

While the annual consumption of sand and gravel in Canada ranged between 10 and 15 tons per capita in 1976[2], no quantitative information is available regarding the possibility of depletion of natural mineral aggregates in the Edmonton area. The purpose of this thesis is to project the aggregate requirements of Central Alberta to the year 2007; to compare the requirements with available supplies of aggregate; to discuss the production and marketing of aggregate; and to examine the implications of provincial and municipal government regulations on potential supplies.

The geographical area covered by this study is 17,172 square miles in size and includes all or portions of 23 counties, municipal districts and improvement districts within 70 miles of Edmonton. The map in Figure 1[3] illustrates the orientation of the study area in Alberta.

Previous studies have found that population growth is the most significant explanatory variable in the demand

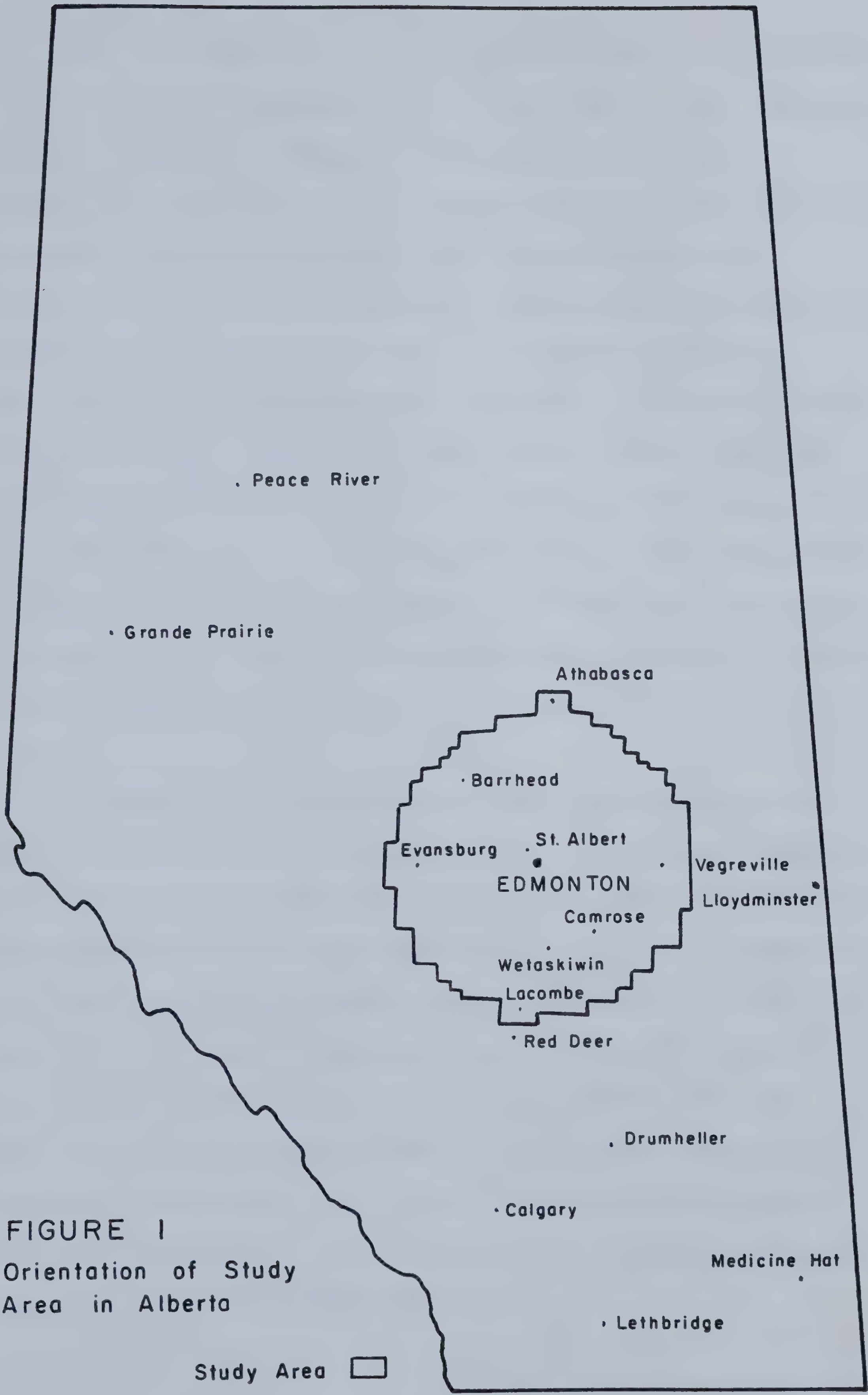

FIGURE 1
Orientation of Study Area in Alberta

increase for aggregates. This study uses data on aggregate reserves in the Edmonton area as contained in the "Edmonton Regional Aggregate Study"[4] conducted by the City of Edmonton. Population growth figures produced by the City of Edmonton Planning Department and the Alberta Bureau of Statistics[5] are used to predict future numbers of households in the region and the province. A linear regression analysis of total construction spending in constant dollars versus absolute numbers of households is used to provide estimates of future construction spending. The proportion of that spending which is accounted for by sand and gravel is determined, providing a means of estimating the tonnage of materials consumed by the populations expected to reside in the study area at various times over the next thirty years.

Chapter II presents background information on the sources, extraction and processing of aggregates. Chapter III analyzes the mechanisms involved in forming the prices of aggregates as well as determining the level of reserves and the nature of aggregate supply elasticity. Chapter IV contains a review of aggregate prediction models used in other studies and Chapter V is the description of the application of the model used in this study. Chapter VI describes the effect that current land use plans have on aggregate reserves in the area and is followed by a chapter on Conclusions and Recommendations.

CHAPTER II

THE ORIGIN AND PRODUCTION OF AGGREGATES

Surficial Geology

To put this study of the most basic building material into perspective, this chapter presents a discussion of how aggregates came to be available in the form they are. As well, information is included on the production and use of aggregate and the means employed to gain legal access to aggregate bearing land. The latter sections of the chapter deal with the costs involved in producing sand and gravel.

Aggregates are combinations of minerals which, in turn, are chemical compounds containing several of the elements. Whatever the mineral content of a sand or gravel, aggregate must exist in sufficient quantity at a particular location, to the exclusion of deleterious material, clay, silt and organic matter, to be a viable source. Materials

meeting these criteria are classed into three categories in the Edmonton area according to their time of deposition: preglacial, glacial or recent (fluvial).

Although the Earth's existence is thought to date back many million years it was only 9,000 to 30,000 years ago that massive accumulations of ice, starting near northern Hudson's Bay, slowly advanced over the continent causing deposition of a sheet of ice estimated to be 5,000 feet thick over what is now the Edmonton region. At least two separate periods of glaciation took place over Alberta, with the last obscuring most of the effects of the previous glaciations and determining the location, quality and quantity of our current deposits of mineral resources. Glaciers abraded, resorted, shaped and deposited existing surficial deposits of materials and, where it was within reach, shaped the bedrock underlying surficial deposits.

In advancing and receding, the glaciers blocked normal drainage channels creating new rivers and large lakes, to drain glacial meltwater, which eventually disappeared after the glaciers had melted. These drainage courses were locations for the deposition of the large quantities of material picked up by the glaciers in their movements, resulting in concentrations of useful aggregates. Glacier produced formations can bear from 15 to 40 percent large, crushable material.

Glacial aggregate deposits are normally considered to be of low or moderate quality. The randomness of glacial

movement and material deposition means that the sizes deposited are poor in selection and the materials generally include numerous undesirable components such as coal, clay and organic material.

Usable preglacial aggregate deposits are relatively rare and occur only where a deposit of granular material, formed before the periods of glaciation, exists close enough to the surface to be exploited. These deposits are normally found in the deep buried valleys of preglacial rivers (thalwegs) or on higher ground when a preglacial deposit has been moved and redeposited by a glacier. Preglacial deposits can be quite free from deleterious matter because of the consistency of their mode of deposition and for that reason are highly prized for concrete aggregate.

Recent deposits occur along the present locations of streams, rivers and lakes and are formed by the washing and sorting action of the water in much the same way as preglacial deposits were formed. However, because current waterways have washed through debris deposited by glaciation, recent materials are normally more similar in quality to glacial deposits than they are to preglacial materials because of the significant amount of deleterious matter usually found in them.

Figure 2[6] illustrates the relationship of the stratas in which preglacial, glacial, and recent deposits are found.

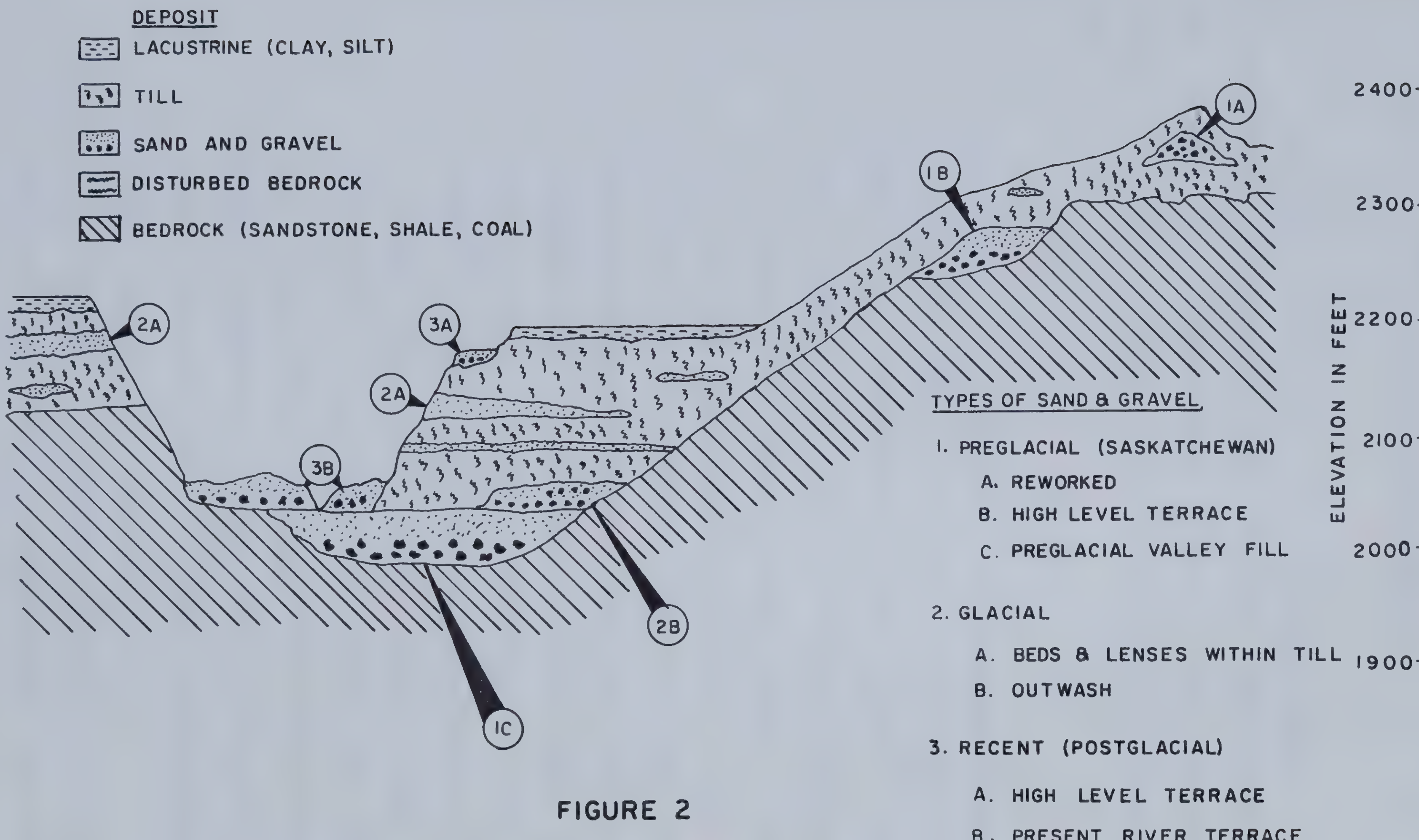

FIGURE 2

SCHEMATIC SHOWING RELATIONSHIP OF AGGREGATE DEPOSITION STRATAS IN THE EDMONTON AREA

Extraction Procedures

The steps required in extracting aggregates, as summarized by the Underwood McLellan and Associates Ltd. study group[7] are listed below. Figure 3[8] is a diagram showing the typical flow of operations for an extraction facility.

1. Discovery - The location of an aggregate deposit can be determined by the occurrence of granular materials on the surface of the ground or from a visual examination by an experienced geologist and the proximity of nearby rivers, lakes, valleys or other telling topographical features. Maps of surficial geology features and soils surveys produced by the Research Council of Alberta, the Geological Survey of Canada or other agencies show the locations of surface features which are indicators of the whereabouts of sand or gravel. Air photo interpretation, air-borne E-Phase resistivity surveys and drilling at sites so determined, allow confirmation of the presence of economic deposits. In addition, exploration for mineral deposits can be carried out by seismic or surface resistivity surveys.
2. Clearing - Once an aggregate deposit is located, trees and other surface material are removed.

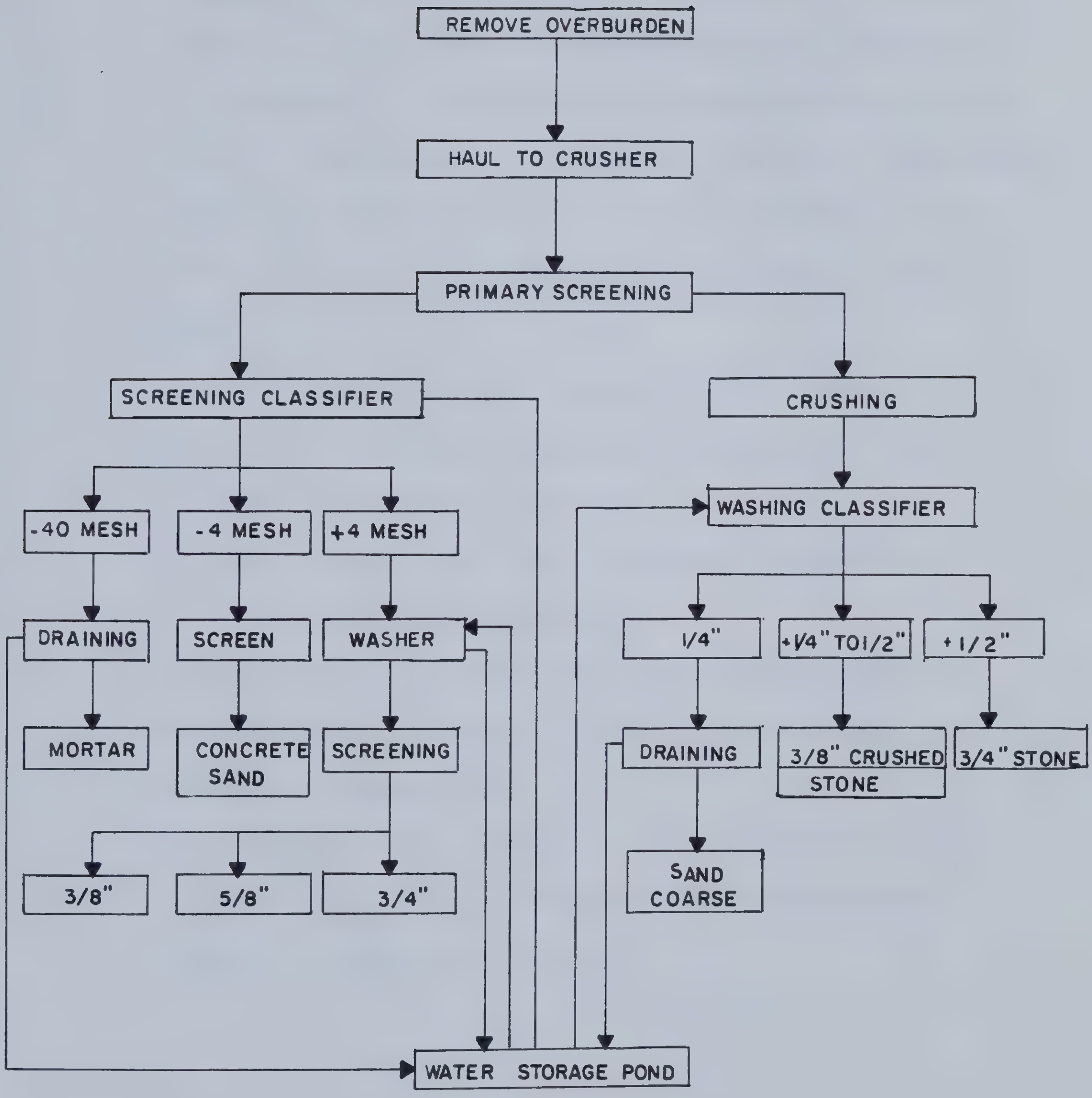

FIGURE 3

FLOW DIAGRAM- SAND AND GRAVEL EXTRACTION AND PROCESSING OPERATION

3. Stripping - The topsoil and subsoil are removed from the location as required. Commonly called overburden, the thickness of the soil overlying a source is important in determining the feasibility of a deposit. A rule which seems to have general usage in determining the feasibility of a location, requires that the ratio of the thickness of the overburden to the thickness of the deposit be at most 1:1.
4. Excavation - Once the overburden is removed the gravel is excavated using bulldozers and front end loaders and moved to either a plant site for further processing, to a storage stockpile or directly to a usage location.
5. Stockpiling - To regulate day to day surges in demand both processed and unprocessed materials are stored in stockpiles.
6. Processing - This step includes whatever sieving, screening, crushing or washing is required to render an aggregate useful.

Uses of Aggregates

Table 1 lists typical uses of aggregates.

The utility of an aggregate is determined by the size and quality of the individual particles that make it up.

TABLE 1

USES OF AGGREGATE

Road Construction

Road Base Preparation

Surfacing on all-weather roads

Asphaltic or Portland Cement Concrete Paving Surfaces

Winter Ice Control - Sanding material

Concrete Aggregate - Sand and rock

Makes up about 88% of the weight of concrete

Roadway Bases and Surfaces

Building Foundation and Structural Materials

Sidewalks, Pipes, Blocks, Pools, Driveways

Asphalt Aggregate - makes up to 95% of the weight of asphalt

Railroad Ballast - stabilization of road beds

Mortar Sand - Fine aggregate material is used in mortar applications

Mine Fill - Replacing displaced ore and other materials

Other Fill - Land filling, Waterworks and other utility trench filling applications

The material sizing of an aggregate is described by an internationally standardized set of sieves which are used to separate a sample of sand or gravel into different size ranges. These sieve sizes fall into three broad classifications. Material passing through a Size 200 sieve or smaller than about 0.075 millimetres in diameter, is classified as silt and clay. Sand is everything larger than Size 200 but smaller than a #4 sieve (4.75 millimetres). Gravel is anything larger than a Size 4 sieve.

Aggregates which are well graded from course to fine sizes, that is, have significant, acceptable, but not excessive portions of material spread throughout the size range of interest, are the most sought after. Materials with less than 5 percent passing through the 200 are "clean" materials. Greater than 15 percent silt and clay denotes a "dirty" material which will likely require further processing to render it useful. The amount passing the 200 which can be tolerated depends on the intended use of the material. For an application requiring material that allows water to drain through it easily, only 0 to 5 percent is tolerable. Most construction uses, that is, those other than for concrete, tolerate 5 to 15 percent silt and clay sizes which allow construction of high density materials. If the silt content is greater than 15 percent the material will have poor drainage properties and be subject to heaving and displacement of position when subjected to freezing and thawing.[9]

The composition of the individual grains of an aggregate determines its soundness, hardness, toughness, durability, porosity and affinity for binders.

In Central Alberta, 54 percent of the aggregate consumed goes directly to the jobsite where it is incorporated either into the road base or is used to provide all-weather surfaces. Another 29 percent is processed into portland cement concrete at ready-mix plants before delivery to the usage site. Sand makes up 12 percent of consumption and is hauled directly to job sites where it is used as bedding for utility lines and foundations, for ice control and as playground sand. A further 5 percent is processed in plants producing asphaltic cement concrete materials.[10]

The Aggregate Industry in Canada

Table 2 provides data for sand and gravel and crushed stone aggregates production for selected years between 1952 and 1977. Table 3 presents indices, with 1952 as a base of 100, for various statistics on aggregate production, costs and general price and population movements.

Sand and gravel production increased 282 percent in Canada between 1952 and 1977, from 103 million tons to 290 million tons per annum. Crushed stone production increased from 18.7 million tons to 132 million tons, a massive 707 percent increase during the same period. The increase for

crushed stone most likely results from an increasing use of crushed stone in the St. Lawrence-Great Lakes area where conventional sand and gravel are in shorter supply. Total production of sand and gravel and crushed stone increased from 122 million tons in 1952 to 422 million tons in 1977 or by 346 percent.

During the same twenty five year period when aggregate production increased by 346 percent, Canada's population increased by only 161.2 percent. The remaining portion of the increase in production for the period resulted from an increase in per capita usage of aggregate which went from 8.4 tons per capita in 1952 to 17.9 tons per capita in 1977, according to these Statistics Canada figures.

The relative price of sand and gravel aggregates increased at a much higher rate between 1952 and 1977 than the price for stone materials, 252 percent as opposed to only 136 percent. In fact, the cost of stone aggregates decreased until 1967 and increased markedly between 1972 and 1977. While the gravel price increased 252 percent, the consumer price index increased 229 percent (1952-1977). The cost of crushed stone increased by only 136 percent during that period.

Aggregates in Central Alberta

The production and distribution of sand and gravel involves business entities of all sizes, ranging from individual operators of the gravel trucks used to transport mineral aggregate from place to place to large corporations employing several hundred people and millions of dollars worth of capital.

In 1971, 2,235 Albertans were employed by aggregate and aggregate product industries such as concrete product manufacturers. An additional 29,245 were employed in the construction and maintenance of highways, bridges, streets and utilities. In the Edmonton Census Metropolitan Area, 995 individuals were employed in quarry, sand pit, stone product and portland cement concrete product industries and 8,670 employed in construction and maintenance activities.[11]

Table 4 shows the distribution of workers in these related industries. Concrete products and concrete manufacture accounted for 725 workers or about 75 percent of the workforce. The industry is dominated by a male workforce.

As shown in Table 5, the total value of construction in Alberta in 1971 was $1,764 million. Of that total, $804 million was for building construction and $960 million for engineering construction. By 1977, the value of building construction for the year was $2,895 million (see Table 5) with engineering construction valued at $3,300 million.

Total construction for the province had a value of $6195 million.

A study conducted jointly by the Alberta Departments of Agriculture and Lands and Forests, released in April 1972, enumerated 153 private producers and 48 regional municipal consumers of aggregate.[12] The study estimated annual production of sand and gravel, in Alberta, in 1971 to be 16.7 million cubic yards. Of that quantity 4.6 million cubic yards were produced from pits on public land and 12.1 million from private land. Of the quantity produced from public land, 2.3 million cubic yards were produced by what was then the Department of Highways and Transport, 1.5 million by private lessees, and 0.8 million by other government departments. The Department of Highways and Transport was found to purchase an additional 2 million cubic yards from private producers and obtained 1 million cubic yards from land purchased by the Department itself.

Table 6 gives the user and source distribution of sand and gravel production in the province for 1971. Private users consumed 7.2 million cubic yards and various government users used 9.5 million cubic yards.

The same study found that royalties in the province ranged from 10 to 26.9 cents per cubic yard with the highest royalties being paid in the Edmonton region. The average royalty in the province was 17.5 cents per cubic yard. It also noted that 60 percent of commercially produced gravel was processed.

The average price in the province for concrete gravel was $2.12 per cubic yard, for road crush; $1.47 per cubic yard and for fill gravel the average price was $0.60 per cubic yard.

Statistics Canada reported aggregate consumption in Alberta during 1976 of 27.7 million short tons (about 23 million cubic yards.).[13] A sampling of 7 producing companies in the province, 5 of which operated in the Edmonton area, provided the data on costs and value added in 1976 given in Table 7.

Table 8 shows the usage distribution of aggregates in 1976 as determined by Statistics Canada's sample while Table 9 documents the processing undergone by the materials. The largest single end use of aggregate, 55 percent or almost 15 million tons was for roadbuilding or maintenance. Use in concrete was next in proportion, 17.5 percent, followed by fill use, 12,8 percent. According to Table 9, in excess of 75 percent of the aggregate produced in the province was processed. The data was extrapolated from a limited sample and so should be interpreted with the limitations of its origin in mind. For that reason, proportions data presented elsewhere in this thesis may not agree with that presented in this section and data based on local information should be assigned greater confidence.

Since surficial deposits of sand and gravel are not regulated by the same mineral rights legislation which cover resources buried more deeply, but instead by the Clay, Marl,

Sand and Gravel Regulations, the aggregate on a piece of land in Alberta is the property of the owner. Large companies with massive mineral requirements normally acquire enough aggregate bearing land, either purchasing or leasing it, to fulfill their requirements for several years hence.

Private Land

Over 95 percent of the land in the study area is privately owned and this has dictated that companies must either acquire ownership of a tract of land or lease exclusive rights to a deposit from its rightful owner. Once a location is determined to be a possible pit site either through its proximity to known deposits, reference to surficial geology maps or aerial photographs or other means, the owner of a property is approached by an aggregate producer regarding arrangements for access to a deposit. Often an owner becomes aware of the potential of his property and he will approach an operator or try to market the gravel himself. The aggregate content of a portion of land is determined by a program of drilling, with holes drilled at regular intervals in a grid pattern over the area, determining the depth, extent and quality of material available. On private land, the operator must then negotiate for mining access to the land and payment for the material extracted.

Depending on the proximity of a deposit to markets and the costs of extraction, a landowner may receive a royalty of from ten to sixty cents for each cubic yard of aggregate extracted from his property.[14] Once access is gained and environmental requirements regarding soil conservation, groundwater use and protection and rehabilitation of the pit site are met through application to the Provincial government, the operator can proceed with mining the aggregate. Municipal governments often require that development permits be taken out on aggregate sites so that land use and transportation corridor restrictions are enforced.

Public Land

Control of aggregate deposits located on crown land is exercised by the Provincial Department of Energy and Natural Resources. Aside from normal lands, the Department also controls the disposition of aggregate reserves located in riverbeds such as those found in the valley of the North Saskatchewan River.

Energy and Natural Resources grants permits, on application, which allow exploration for aggregate on crown land. Once aggregate is located, either a licence or a lease can be obtained for a tract of land.

A licence allows the extraction of a specified

quantity of gravel on the payment of a $10 application fee and a royalty of 15 cents per cubic yard of sand and 25 cents per cubic yard of gravel or sand and gravel mixture removed. In addition, an operating plan must be filed for the proposed activities and a $250 per acre deposit is required toward the rehabilitation of the land to a safe, environmentally sound condition.

A lease is granted for a minimum 40 acre section of land and gives controlling interest in the land for periods of 5 to 25 years on payment of a $25 application fee and $7 per acre per year rental charge. The leases, normally five to ten years in length also require payment of a 15 cent per cubic yard charge for sand and 25 cent per cubic yard charge for gravel or sand and gravel mixtures. The royalties are subject to periodic review. However, no specific review interval exists and rates have stayed constant since the early 1970's. Once again, a $250 per acre security deposit is required to ensure the proper restoration of the work site. The Department is able to utilize the security deposit and recover any additional restoration costs from the operator if the lessee fails to live up to restoration requirements on either a lease or licence.

A licence therefore involves the extraction of a specified quantity of gravel and a lease provides a controlling interest in a property regardless of the quantities available on the land. Before a licence or lease can be awarded, an operating plan must be approved which

ensures protection of fish, wildlife, watercourses and lands.[15]

Costs of Production

The owner of a deposit of aggregate gets paid from 10 to 60 cents per cubic yard for his aggregate in its undisturbed state, in the ground. How then does the final price of an aggregate grow to become 3 to 5 dollars per ton? Table 10 shows a generalized breakdown of the component costs, in 1977 dollars, of producing an aggregate product which requires crushing. These costs of production were derived from consultations with sources in local industry and include a return to capital component.

Costs are incurred even before extraction of the gravel begins. The cost of exploring a site for aggregate will range from 3,000 to 15,000 dollars, amounting to a cost of about 1.8 cents per ton of finished product.

The first operation required in extracting gravel, as outlined previously, is removal of overburden or stripping. Depending on the ratio of the thickness of overburden to the thickness of the deposit, the cost of stripping contributes from 45 to 55 cents per ton of aggregate. Removal of pit run gravel from the pit face to a crusher will cost 20 cents per ton and crushing of the gravel will cost from \$1.25 to \$1.50 per ton. Movement of the crushed aggregate to a

transport truck or to a stockpile and then to a transfer truck will cost approximately 20 or 40 cents per ton respectively.

Scaling or weighing of the aggregate for accounting purposes will cost from 15 to 25 cents per ton. Other costs incurred "before the aggregate leaves the pit site" include 50 cents per ton for backfilling the void left by the removed material and could include 10 to 20 cents per ton for dewatering. Dewatering is required when the aggregate must be recovered from a location which is below the existing water table level, a situation which results in a tendency for the pit to flood. Costs are then incurred in pumping seepage water out of the pit and allowing for drainage of the extracted aggregate. Assuming averages for the preceeding costs and no dewatering, the pit head cost of producing crushed aggregates will average about $3.10 per ton.

Pit Depths

The thicker the layer of aggregate at a location the more economical is extraction. Pits are normally excavated in terraces where a 10 to 15 foot thick layer is extracted at a time and removed, using an access road built down into the pit, to a crusher, job site or storage pile. As a layer or terrace is completed, the next layer is started,

immediately below what has been extracted. An access road is made and the terracing process continues until the seam of gravel is exhausted.

The gravel walls of a pit are normally quite stable because of their good drainage capabilities but, if necessary, can be sloped or terraced for stability at a cost of 2 to 4 cents per ton of aggregate. This would increase the share of "removal to crusher" costs, as shown in Table 10, by one percent. The only other major marginal cost that can be incurred with deeper pits is a dewatering cost which, as previously mentioned, occurs when workings are below water table levels. A marginal cost of 10 to 20 cents per ton is incurred for dewatering and the additional cost could add 5 percent to the cost of aggregates.

Classification of Costs

The capital cost of an extraction operation will vary with the scale of the operation and the quality of the aggregate being processed.

A simple, portable crushing plant with a capacity of 100 tons per hour, plus the associated handling and weighing equipment has a capital cost of from \$150,000 to \$200,000 in 1977 dollars. These smaller capacity plants are relatively uncommon in the study region because the presence of a large market makes it feasible to operate larger, permanant,

plants to supply the Edmonton market. Small plants find application in Central Alberta only in rural, small market areas or in rural highway construction projects where production of aggregate is needed in an area for only a short period of time.

A plant with a capacity of 500 tons per hour will have a basic capital cost of from $600,000 to $900,000 in 1977 dollars. However, the use of more mechanized material handling systems and the installation of sophisticated equipment to wash, separate, and dry poorer quality aggregate could cause the price of a facility to exceed $2 million.

The cost breakdown for a representative large production plant, that is, one having a capital cost of about 2 million 1977 dollars and a capacity of 700 tons per hour, in close proximity to Edmonton shows that labor costs account for 30 percent and operating and capital recovery costs for 70 percent of production costs. The non-labor costs average 55 percent for operating and 15 percent for capital recovery costs. Since personnel requirements are similar regardless of the size of the plant, labor costs may be responsible for up to 60 percent of the cost of running small operations.

Transportation

The majority of Edmonton's aggregate comes from sites within 20 miles of Edmonton although some comes from as far away as 60 miles. Aggregate from all but the farthest sources is hauled to market destinations by transport trucks. Aggregate is hauled in by railroad from deposits at locations thirty to sixty miles away only when needed in very large quantities.

Up to the point where aggregate is transported away from the extraction site, the aggregate industry is generally well integrated vertically. Exploration for materials and the mining and crushing of aggregate are most frequently carried out by the same organization. However, transportation of aggregates from pits to manufacturing plants which utilize aggregate or directly to job sites is generally accomplished via the use of private, owner-operated trucks.

These trucks may be required at a particular location for only part of a season or the calendar year. As well, trucking operations are subject to the uncertainties of weather. Under these conditions a system utilizing individual operators allows flexibility in the allocation of trucking resources and avoids the possibility of large amounts of unused trucking capacity. This type of flexibility in transport capacity would be more difficult for a company with operations centered in a particular area.

Where a specialized segment of the industry is involved, such as the mixing and transportation of portland cement concrete, or a certain volume of work is assured as in the case of hauling asphaltic cement concrete, a company may have a completely integrated operation including paving construction services. The company may produce from a pit it owns, look after the truck or railway transportation of aggregate to its concrete plant and use its own trucks to deliver concrete. It is estimated that such operations account for about 34 percent of all aggregate usage making the production of concretes an important subcomponent of the aggregate utilization industry.[16]

Industry Structure

About ten (out of thirty seven) producing companies account for 70 percent of all aggregate production in the region (based on 1976 data). The aggregate industry has evolved in such a way as to concentrate a major portion of productive capacity within a small group of companies. The Provincial government produces approximately 20 percent of the materials consumed while municipalities and small producers account for the remaining 10 percent of production.

Production in the rural portions of the area and for the smaller towns is by small, privately held companies.

The same is true for the larger towns except in the case of Camrose, Wetaskiwin and Ponoka where the Revelstoke company has operations. Headquartered in Calgary, the Revelstoke company produces lumber in British Columbia and operates building supply retail stores, produces aggregates and manufactures concrete in Alberta. Within metropolitan Edmonton, a variety of company structures can be found within the industry. Smaller companies like Bulat Sand and Gravel are privately held. Some of the larger companies, like Apex Sand and Gravel are privately held and are engaged only in the production of aggregates.

However, the major forces in the industry are parts of large, sometimes, well-integrated companies. Steel Brothers Canada Limited, headquartered in Richmond, British Columbia, produce lime as well as aggregate and also wholesale building supplies. TBG Contracting Ltd. also is involved in real estate transactions and is owned by Ashland Oil Canada Ltd. Alberta Concrete Products is owned by Canada Cement and Loran which engage in cement manufacturing, general contracting, heavy construction and project management. On a larger scale, Northwest Sand and Gravel is owned by Turbo Resources which operates in oil and gas, chemicals, marketing, real estate, manufacturing, mining, plastics, oilfield servicing, building and construction; in short, a highly integrated company as well as diversified. The most significant and most integrated company is Genstar. Genstar's Standard General produces

aggregate and asphalt as do Northern Gravel; Rex Underwood and Consolidated Concrete produce concrete; Inland Cement, cement; Con-Force, concrete products; Truroc, gypsum wall board; Abbey-Glen develops real estate and Engineered Homes and Keith Construction produce buildings. The company is also involved in heavy construction, chemical manufacture, venture capital, import-export trade, investment trading, marine transport and mining.

Conditions of Entry for New Producers

While entry to the aggregate production industry in the metropolitan Edmonton area is becoming increasingly more difficult, a number of new producers have entered the local market recently. The most successful entries involve acquisition of existing companies.

With the rapid expansion that is taking place there is a ready market for materials. The most significant problem is one of obtaining supplies. Existing companies have acquired the most economic supplies of materials and have arranged for supplies for an extended period into the future. A newcomer to the industry will have a distinct disadvantage in acquiring supplies. Most crown lands are available to provide Transportation Department needs only and very little crown land is otherwise available within 70 miles of Edmonton.

Finally, to be competitive in the metropolitan market, a new producer must be able to produce on a large scale to be able to take advantage of the economies of scale available to existing major producers. The combination of having to locate sizable quantities of price-competitive materials in close proximity to the market and having to start right off with a large physical plant makes entry into this portion of the market increasingly more difficult.

Outside of the metropolitan market area, demand for aggregate is more restricted but growing. Sources of supply are more readily available, to the north and west anyway, and it is possible that public land may yield sources of aggregate. Smaller equipment is more appropriate and therefore equipment acquisition involves less of an investment. In general, entry into the industry is easier in rural central Alberta than in metropolitan Edmonton because sources are less scarce, equipment is less costly and the markets are not large enough to attract the large producers.

The Effect of Government on the Industry

The common complaint about excessive government restriction has also been registered by the aggregate industry.

In the past, aggregate production was a matter of

locating, producing and selling. A more complex society, conscious of environmental impact, makes the process somewhat more complicated. Environmental impact and land use restrictions are in effect now to reconcile environmental quality with the production of aggregates. Site development and restoration are important with the effect of new operations on neighbors and transportation corridors carefully studied. Alternate land uses such as recreation and agriculture are weighed against the extraction of aggregate supplies. Land restoration is an important issue under these circumstances.

Regulations which affect aggregate production in Alberta are reviewed in Appendix 3.

The government's role as a producer of aggregate has also affected the industry. Government's ability to obtain its own supplies at lower cost has removed that demand from the public sector. However, at the same time, government has been competing with private enterprise for sources of supply. The net effect has probably been, since government can produce supplies at cost, to decrease the cost of aggregate slightly. As government has the only source of renewable supplies within its control, river-bed aggregates, it will continue to have a, however slight, moderating influence on prices.

The low royalty rates charged for reserves on crown land may have kept royalty rates down at one time. However, since there is little crown land left in the study area,

current royalty rates likely exert little influence on the central Alberta market.

TABLE 2

CANADIAN PRODUCTION OF AGGREGATE

Selected Years: 1952-1977

(1000's tons)

Year	Sand and Gravel	Stone
1952	102,896	18,726
1957	159,830	40,282
1962	181,249	47,553
1967	209,666	80,636
1972	225,194	80,203
1977	289,803	132,450

Source: Statistics Canada, _Canada's Mineral Production_. Catalogue 26-202, 1952-1977.

TABLE 3

CANADIAN AGGREGATE INDUSTRY

GROWTH INDICES

(1952=100)

YEAR	Gravel Prod'n	Stone Prod'n	Gravel Value $/ton	Stone Value $/ton	C.P.I.*	Population: Canada
1952	100.0	100.0	100.0	100.0	100.0	100.0
1957	155.3	215.1	115.2	89.3	104.6	115.0
1962	176.1	253.9	131.1	84.1	111.9	128.7
1967	203.8	430.6	137.2	75.6	126.7	141.4
1972	218.9	428.3	158.5	78.2	154.1	151.3
1977	281.6	707.3	252.3	135.9	228.8	161.2

---

*excluding food items

Source: Statistics Canada, The Consumer Price Index, Catalogue 62-001. Prices and Price Indexes, Catalogue 62-002.

TABLE 4

EMPLOYMENT IN AGGREGATE RELATED INDUSTRIES
IN EDMONTON - 1971

Industry	Employment		
	Male	Female	Total
Clay Products	30	5	35
Cement Manufacture	150	35	185
Stone Products	15	5	20
Concrete Products	400	10	410
Ready Mix Products	290	25	315
Glass and Glass Products	25	5	30
Total	910	85	995

Source: Statistics Canada, 1971 Census of Canada, Industries, Catalogue 94-742, Vol. III, Part 4

TABLE 5

VALUE OF CONSTRUCTION WORK - ALBERTA 1971 and 1977

Type of Structure	Value (1000's of Dollars)	
	1971	1977
Building Construction	804,260	2,895,463
Residential	453,900	1,813,730
Industrial	38,324	107,976
Commercial	116,211	580,794
Institutional	129,376	149,264
Other	66,449	243,699

TABLE 5--Continued

Type of Structure	Value (1000's of Dollars)	
	1971	1977
Engineering Construction	959,935	3,299,950
Marine	914	3,219
Road, Highway		
Aerodrome	123,559	369,580
Waterworks and Sewage	54,942	183,119
Dams and Irrigation	10,806	22,745
Electric Power	86,877	289,822
Railway, Telephone and		
Telegraph	58,944	171,010
Gas and Oil	550,761	1,563,116
Other	73,132	697,339
Total Construction	1,764,195	6,195,413

Source: Statistics Canada, Construction in Canada
Catalogue 64-201, 1971 and 1977

TABLE 6

ESTIMATED SAND AND GRAVEL PRODUCTION IN ALBERTA

1971

User	Source	Production of Sand and Gravel (cubic yards)
Commercial Sand & Gravel Operators	Private and crown Owned Pits	7,207,000
Department of Highways & Transport	Crown Pits	2,291,000
	Private landowners and D.O.H. & T. pits	3,001,000
Counties and M.D.'s	Private landowners and County and M.D. pits	2,626,000
	Crown pits	588,000
	Private operators processed gravel	548,000

TABLE 6--Continued

User	Source	Production of Sand and Gravel (cubic yards)
Other Government Departments	All Sources	265,000
Special Areas	All Sources	222,000
Total		16,748,000

Source: Ron J. Miller, A Study of Sand and Gravel Disposition in Alberta. A report for the Economics Division, Alberta Department of Agriculture in cooperation with Lands Division, Alberta Department of Lands and Forests, April, 1972.

TABLE 7

AGGREGATE PRODUCTION COSTS - 1976

No. of Companies Surveyed	7
No. of Employees	
Mining	163
Including Support	220
Payroll and Average	
Mining	$2,848,000/$17,500
Including Support	$3,852,000/$17,500
Cost of Fuel and Electricity	$653,000
Cost of Materials	$6,030,000
Value Added	$11,209,000
Value of Production	$17,892,000
Total	$17,892,000

Source: Statistics Canada, Sand and Gravel Pits-1976, Catalogue 26-215, August, 1978.

TABLE 8

END USE DISTRIBUTION OF AGGREGATE - 1976

Application	Tons (1000)
Fill	3,462
Roads (Roadbeds, Surfaces)	14,996
Roads (Ice control)	244
Concrete Aggregate	4,710
Asphalt Aggregate	2,079
Railroad Ballast	1,099
Mortar Sand	72
Other	344
Total	26,976

Source: Statistics Canada, Sand and Gravel Pits-1976, Catalogue 26-215, August, 1978.

TABLE 9

PROCESSING DISTRIBUTION OF AGGREGATES - 1976

Material	Tons (1000)
Sand	
Washed and screened	1,640
Screened	2,497
Gravel	
Screened	122
Washed, Screened, Crushed	3,638
Washed and Screened	9,927
Not Processed	6,601
Not Accounted for	2,471
Total	26,996

Source: Statistics Canada, <u>Sand and Gravel Pits-1976</u>, Catalogue 26-215, August, 1978.

TABLE 10

COMPONENTS OF AGGREGATE PRODUCTION COST

1977

Cost Incurred	Percent of Production Cost
Royalty Paid to Owner	3.2
Exploration	0.6
Stripping of Overburden	16.0
Removal to Crusher	6.4
Crushing	44.9
Removal to Transfer Truck	6.4
Weighing	6.4
Backfilling Excavation	16.0
Total	100.0

Source: Obtained from a survey of area aggregate producers, 1977.

CHAPTER III

PRICE, DEMAND AND SUPPLY ANALYSIS

Having examined more basic information as to how natural aggregates originated and what is involved in getting them to market, this chapter explores the economics of the process in more detail.

What substitutes are available and how would their existence affect something called "reserves" of natural aggregates? These topics are discussed as are the factors which influence prices and supplies of aggregates. Finally, an attempt to determine the supply elasticity of aggregate preceeds a review comparing Edmonton prices to those in areas where aggregates are more scarce.

Demand for aggregate is very price inelastic. Aggregate is a derived demand, used as one of many inputs in building and engineering construction; in addition, it has low technical substitutability. In the case of building

construction, the cost of aggregate is a small fraction of the total outlay. About 300 tons of aggregate, mostly in the form of concrete will be used in a 1200 square foot house with a driveway and garage. The cost of the concrete will amount to about 8 percent of total cost, half of which will be represented by the cost of the aggregate itself. As a minor cost component in house construction, aggregate will tend to have a low price elasticity.

On the other hand, aggregate can account for 20 to 30 percent of the cost of other construction (roadbuilding). However, in this case it is the low technical substitutability of aggregate which results in low price elasticity.

Potential for Aggregate Substitutes

With conventional aggregates costing about 5 dollars per ton to deliver to an Edmonton job site, hauling distances and royalty fees would have to increase significantly to make materials other than natural aggregates attractive for use.

There are a number of possible substitutes for current sources. Ash, clay, sand, soil, solid waste, recycled portland cement and asphaltic concrete, imported aggregates and deep aggregates were all found to have potential as replacement materials in a study conducted by

the City of Edmonton.[17]

Ash, clay, sand, soil or solid waste can all be used, as is, to replace aggregate in many current applications. At present, because the use of these materials is very new, considerable further research is required into applications of these substitutes before confidence, in a technical sense, is established in their use. More quality control and determinations of long term material strengths, for example, may be required during the installation of these replacements.

These same five materials can also be used to produce manufactured or synthetic aggregates. Manufactured aggregates are made by sintering or heat treating a raw material in a process which forms hard, light or normal weight agglomerations which can be produced in various sizes and used as aggregates. However, manufactured aggregate, produced for a specialty portland cement concrete market, currently costs in the vicinity of 13 dollars per ton or more than two and one-half times the cost of natural aggregate in the Edmonton area. Relative prices will have to change substantially before manufactured aggregate becomes competitive.

Portland cement and asphaltic concrete wastes are in relatively limited supply and although useable as fill or base materials at costs near to or slightly higher than present aggregate sources, they do not appear to be capable of supplying any more than 1 or 2 percent of the Region's

requirements.

"Imported" aggregates are the same as local supplies but are considered separate from study region reserves for the purpose of this thesis. Considerable quantities of aggregate exist in the regions to the north and west of Edmonton. If need be, the Rocky mountains could be tapped as a source of crushable stone so that there is literally no possibility of running out of aggregate at any time in the future. All that is required to make these sources viable for Edmonton region use is, once again, for prices to rise sufficiently to pay costs.

The use of bulk transportation can allow aggregate to be transported long distances at a relatively modest increase in price. While incremental truck transportation costs are typically 14 cents per ton mile in Edmonton, prices for finished concrete products in Norfolk, Virginia (see Table 14) where crushed stone must be transported from 250 miles away averaged only five to eight dollars more per ton. That is, if incremental costs were to be the same in Norfolk's case (at 14 cents per ton mile for, say, 240 miles) their aggregate would cost an additional $33.60.

A final alternate material can be derived by mining aggregates located well below the ground surface. Aggregates 200 feet down or deeper are mined by constructing shafts in much the same way as coal is mined. The technique involves somewhat less surface disturbance than normal pit operations and mining can take place closer to urban areas.

The costs involved can not be established at present but, again, indications are that production of deep supplies will require considerably higher aggregate price levels.

Definition of "Reserves"

The word "reserves" can have different meanings when used to describe stores of aggregate. The definition most frequently used in this thesis refers to the quantity of sand and gravel which can be mined using conventional open pit techniques. These are "engineering reserves" and include all sand and gravel available within the study region, subject only to the practical or engineering limitations on the extraction of material. Aggregate could be made available through unconventional production means such as deep shaft mining but those techniques are not currently used for production and involve much higher production costs.

"Economic reserves" are those reserves which can profitably be mined at current price levels using presently known techniques and include aggregate deposits which, as a rule, are nearest to the market. Although vast reserves of aggregate exist in the study area, only a small portion of those reserves are near enough to markets to be profitable to work at present prices. "Protected reserves" define the portions of the engineering reserves which are protected

from being lost as production sources by the imposition of land use restrictions.

It should be remembered throughout the discussion of reserves presented in this thesis that the "engineering reserves" of aggregate available to Central Alberta are in no way physically restricted to the study area under consideration. As more materials are needed, a condition which will be reflected in real price increases, sources will be developed which are located beyond the artificial boundaries of "Central Alberta" as defined by this study and shown in Figure 1.

Factors Determining Supply Characteristics

An examination of the relationship of aggregate supply and demand using the classical model can help illustrate the influence of factors affecting supply. Figure 4 depicts the supply and demand curves that would be typical for this industry. The steep negative slope of the demand curve reflects the highly price inelastic character of demand for sand and gravel in the range of prices and quantities with which we are concerned.

Concentrating on quantities of supply, two plateaus of supply can be identified. "Stock" supplies are considered to be available engineering reserves of sand and gravel and are based on sources represented by the given

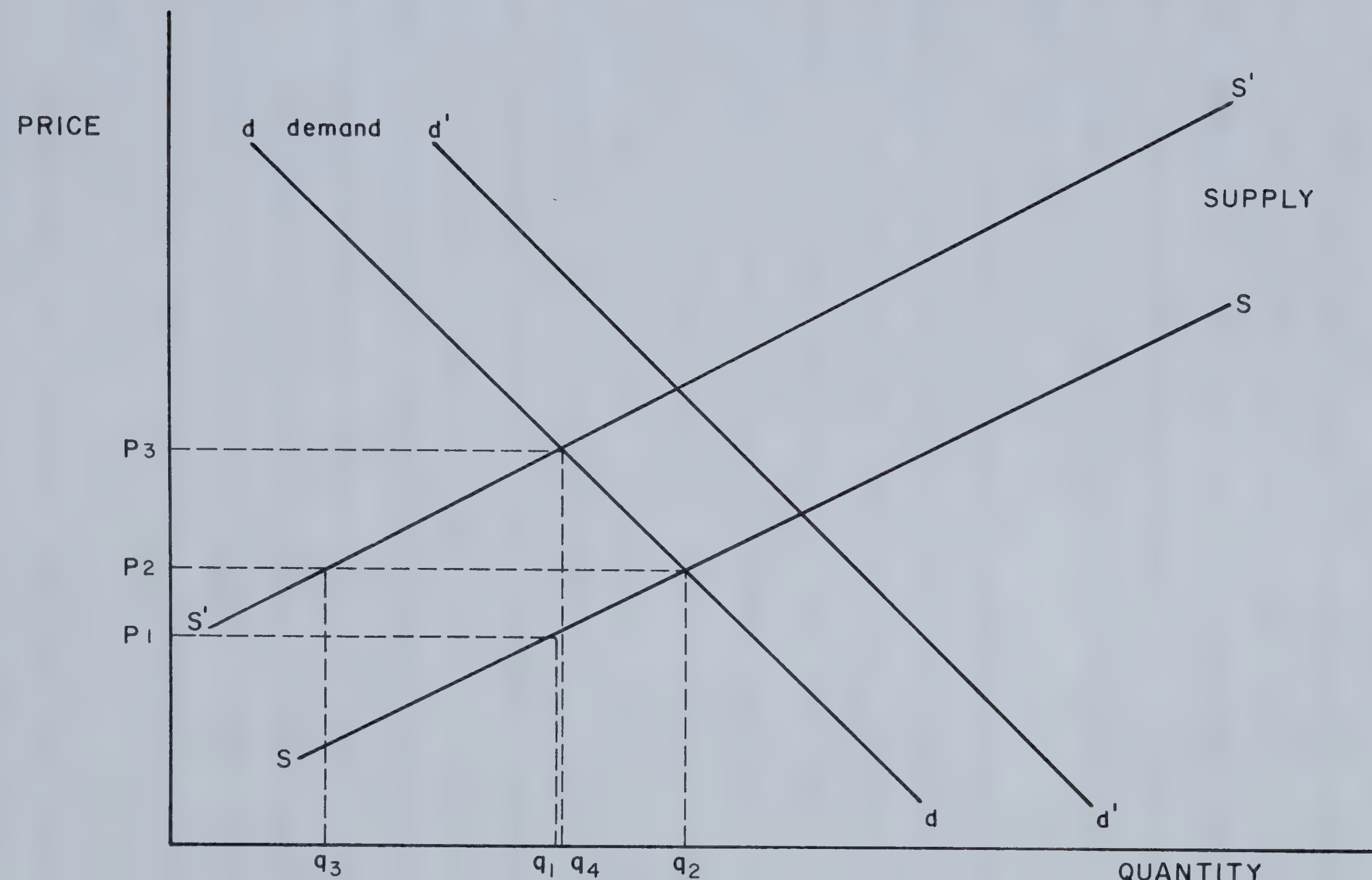

FIGURE 4. CONVENTIONAL SUPPLY AND DEMAND CURVES

natural distribution of materials in an area and are limited only by the physical existence of those reserves and the technology available to mine a portion of them.

Stock supplies decrease as aggregate is consumed but, given a level of extraction technology, do not fluctuate. "Flow" supply, on the other hand, is the supply of material actually being marketed by producers. It is this supply which can be affected by changes in demand and which is shown in Figure 4.

The low end of the supply curve represents the supplies available at low prices: materials close to the market or low quality materials close enough that savings in transportation costs are enough to cover the cost of improving the materials to a marketable quality. That is, when price is p_1 (see Figure 4), the quantity of material that can be produced is q_1. That quantity, q_1, is made up of the nearest, highest quality materials. Actual prices adjust to allow the production of that quantity of gravel which is necessary to supply local demand. Therefore, at price p_2 (Figure 4) enough more distant or lower quality aggregate can be produced to satisfy the quantity needed (q_2) to provide equilibrium with demand. The incremental difference in price (p_2-p_1) is enough to induce production of the additional quantity (q_2-q_1) necessary to satisfy demand, q_2.

Decreasing stock supplies (engineering reserves) shift the supply curve ss in Figure 4 to the left to s′s′.

Instead of supplying quantity q_2 at price p_2, the industry is willing to supply only q_3. A new equilibrium point is established at price p_3 and quantity q_4. The quantity is slightly reduced because while one is still on the same highly inelastic demand curve, a decrease in consumption due to a slight amount of price elasticity occurs. The change, in reality, may be so slight as to be immeasurable and is normally more than compensated for by growth in demand due to economic expansion. Significant changes in demand will result only from actual shifts in the demand curve, as from dd to d′d′ in Figure 4. Such shifts will occur only with changes in household income, economic activity or population growth.

Since the supply function is readily identifiable as the flow supply and is essentially stable over a period of several years, any changes in supply which have occurred over the last several years will be due to shifts in the demand curve. Data on supplies delivered over a recent five year period is available as well as the corresponding prices and will be used in an effort to estimate the price elasticity of supply later on in this chapter.

Figures 5, 6 and 8[18] present an engineering oriented analysis of factors determining supplies.

Figure 5 illustrates the relationship between the price of a mineral and the demand for it as described by Medford.[17] The price of aggregate is found to be a function of not only demand but, because of the finite quantity of

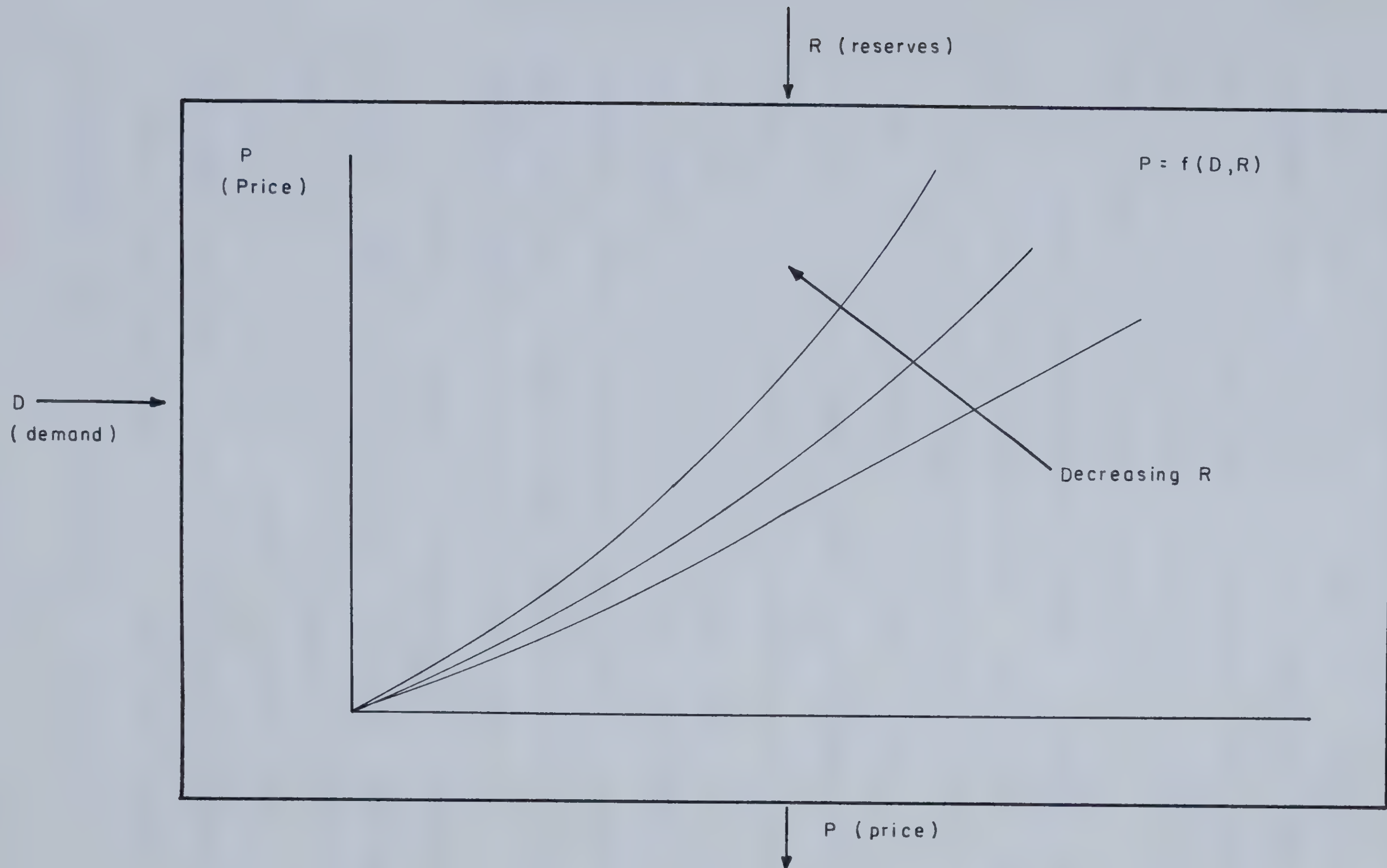

FIGURE 5

RELATION BETWEEN AGGREGATE DEMAND AND PRICE

economic reserves, a function of economic reserves as well. A decrease in demand can cause a decrease in price while if the depletion of reserves could be reversed, price would also decrease. The curves in Figure 5 are actually the supply curves ss and s′s′ in Figure 4. Just as the level of reserves determines the curve, in Figure 5, which is applicable at a given time, a change in the state of reserves determines whether supply curve ss or s′s′ or some other supply curve is used in Figure 4.

Figure 6 shows how the tenor, or grade, of material which is extracted is determined. When prices are low extraction of only high grade materials having a low cost of exploitation is possible. As prices increase it becomes possible to utilize lower grade sources because the higher prices can cover the cost of the additional processing required, that is, it is feasible to move to situations described by the curves to the right of Figure 6. The situation can be represented, classically, by disaggregating supplies into different supply curves, each representing a different source of material, as in Figure 7.

Line ss in Figure 7 represents the supply curve for naturally high grade materials. Line s′s′ represents supplies of materials which must be processed before they are of similar quality. Figure 7 assumes that we are interested only in a supply of high quality materials for the moment and, for simplicity, that both types of material are the same distance from market. At price p_1 it is

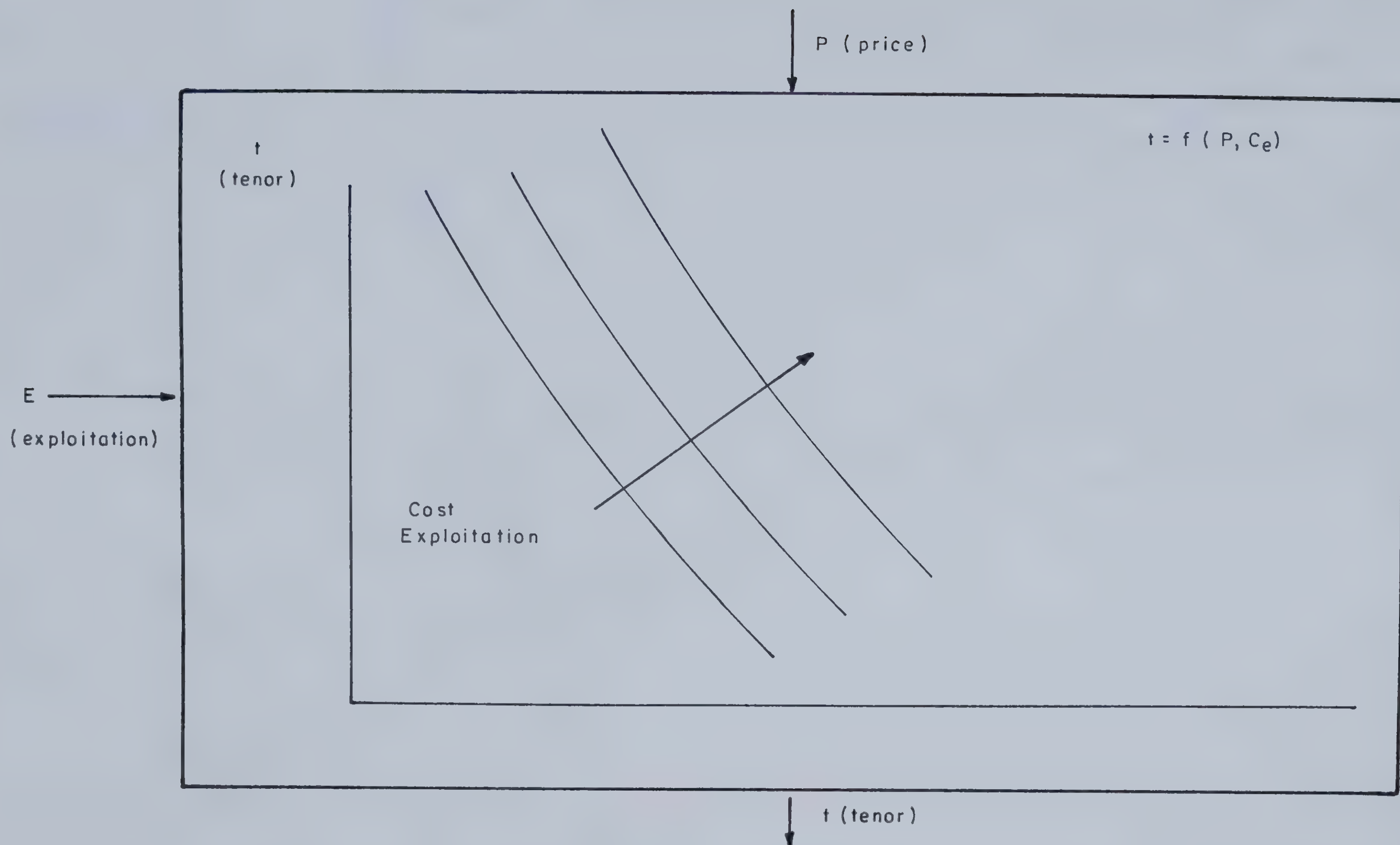

FIGURE 6
RELATION BETWEEN TENOR AND PRICE

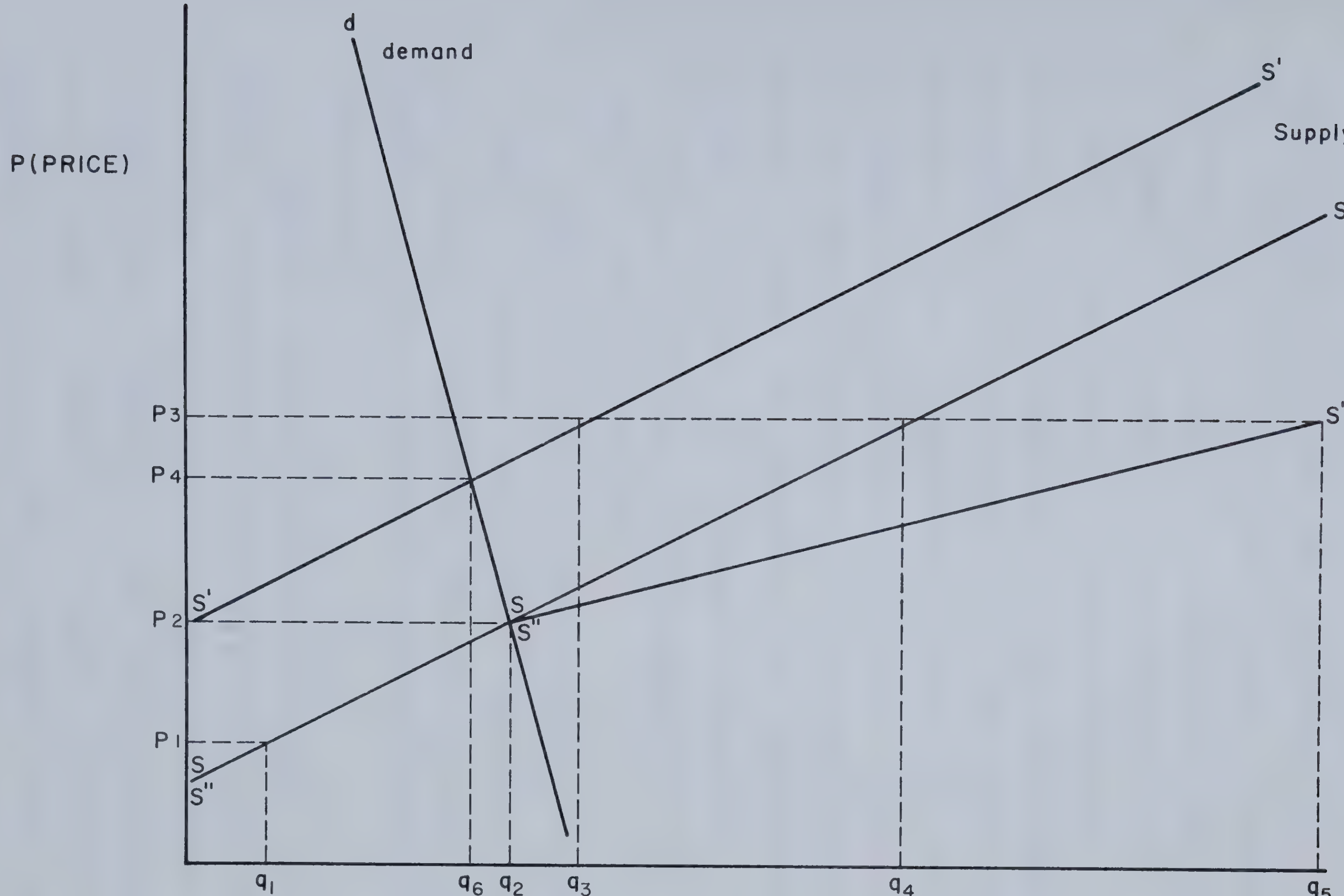

FIGURE 7. DIFFERENTIATED SUPPLY CURVES

possible to produce only quantity q_1 and only naturally high quality materials. In fact, it is not possible to produce beneficiated material until the price reaches p_2. At that price, the total amount of quality material produced begins to contain a contribution from beneficiated supplies. This is illustrated in Figure 7 by the fact that line s"s", representing total supplies, overlies line ss up to that point. At price p_3 both naturally high quality materials and materials obtained through processing are produced, quantities q_3 and q_4 respectively, adding to a total of q_5. This shows that at equilibrium the price is high enough to provide sufficient quantities of a particular quality of material, whatever the condition of the source may be. As the cost of exploitation or processing increases, prices must increase accordingly to allow production of the same grade of material to continue.

Figure 8 shows the relation of quantity of reserves to quality. Economic reserves are a function of tenor. The lower the quality of material that price will allow to be produced the higher the level of reserves of materials which become available.

Economic sources of materials at present are so plentiful in the Edmonton area that price is governed primarily by demand. High quality materials will be in good supply in Central Alberta for some time so that while the price of exploitation may vary slightly, essentially the same quality of material will be produced. While some

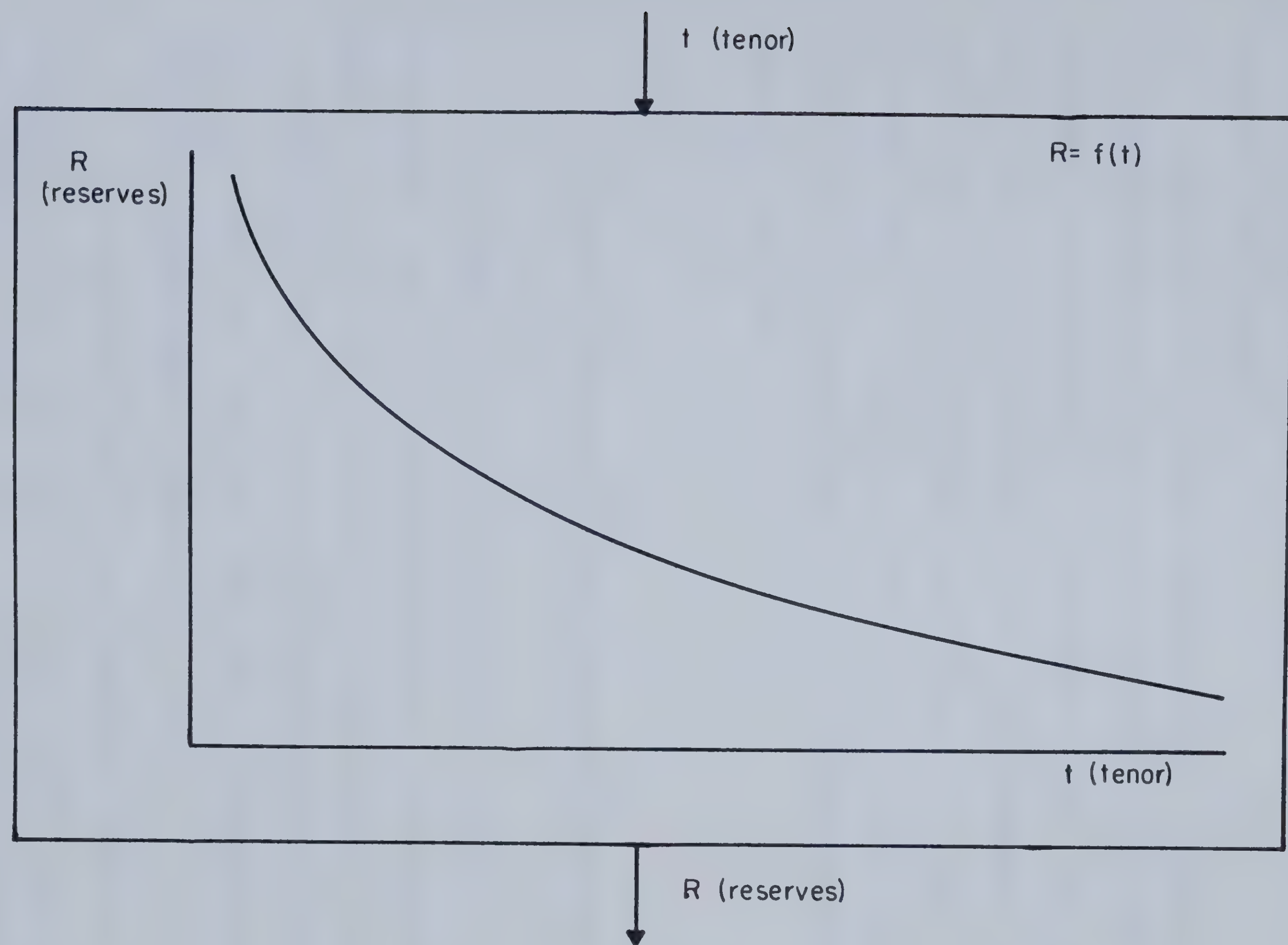

FIGURE 8

RELATION BETWEEN RESERVES AND TENOR

increase in royalties paid to aggregate owners will be evident, the major size of current reserves means that hauling distances need not increase significantly within the next 15 to 20 years.

Reserves of high quality materials in the region are the most limited of the types of material available. However, as the quality of the material available decreases and prices rise accordingly, significant supplies of conventional materials become available at slightly higher prices since it becomes economical to transport quality materials for greater distances or to further process lower quality materials.

Factors Affecting the Real Price of Aggregate

Two factors cause real changes in the price of aggregate, that is, changes other than those resulting from general price level movements. The real price is dependent on increases in transportation costs and, as is the case for any non-renewable resource, the cost of developing and extracting incremental supplies.

As aggregate deposits near a market deplete, aggregate must be transported farther to the point of use, increasing the supply price. Assuming loading costs remain the same regardless of transfer mileage, haulage costs will currently increase, on average, the price of a ton of

aggregate, by about 14 cents for each additional mile hauled. On a $5 ton of aggregate that amounts to a 2.6 percent increase in its price. For a $40,000 house, using 300 tons of aggregate, the increase in costs amounts to only about 0.1 percent for each added mile.

Consider Figure 7 once more. It is not unreasonable to assume that the extraction and processing costs for a particular quality of aggregate are the same regardless of the location of a source. Therefore, the only reason for there to be a difference in the price of those supplies would be if there was a difference in the cost of transporting the material to market. That accounts for the incremental costs associated with incremental supplies. The unit cost of transporting will determine the slope of that line and as costs increase the line will slope more steeply.

A ten mile increase in hauling distance would be a realistic increase since, if urbanization is the cause of a producer's move from an area, a company will likely move well out of the community so as to not encounter such problems again in the near future in response to increased urbanization. A 10 mile increase in haul would cause a 1.0 percent increase in the cost of a house. Using the same 1 percent increase figure, the cost of $786 million worth of building construction would have cost almost 8 million dollars more in 1976. A mile of road using 60,000 tons of aggregate would cost $78,000 more or if aggregate makes up 25 percent of the cost of the roadway, 6.1 percent more.

Where local road construction cost \$86.4 million in 1976 (using a 6.1 percent increase in cost) and Other Construction cost \$136 million (using a 1 percent increase in cost) the total additional cost of a 10 mile increase in hauling to the region would have been about \$15 million in 1976 or 1.5 percent of expenditures.

The other factor influencing the real price of aggregate is the cost of acquiring supplies. As more aggregate is demanded, the price paid to owners of aggregate is bid up. In Figure 7, for example, this would be represented by a movement up the demand curve ss from p_2q_2 to p_4q_6. If enough material is required an additional cost must be incurred to develop new deposits which will have a different basic cost because of varying extraction and processing requirements. The result is a move to a different supply curve as represented by a switch from supply curve ss in Figure 7 to supply curve s′s′.

An individual who owns reserves which are economic to extract stands to profit from such an increase in market prices. As indicated in Chapter II, the fee paid to a land owner for gravel extracted from his land varies from 10 to 60 cents per cubic yard in Central Alberta and is highest at points closest to Edmonton. Although dependent on the quality of the aggregates, as supplies diminish, the cost of 10 and 20 cent per ton aggregates increases to 30 and 40 cents per ton. The effect of a 10 cent rise on these prices is only about one-tenth of the effect of increasing hauling

distances (by 10 miles) but is a significant contribution to real price increases.

The prices shown in Table 11, for the years 1964 to 1977, illustrate the effect of demand on aggregate pricing. While transportation costs rise as the result of the depletion of nearby aggregate reserves or inflation, or at least do not change, royalties are set by long term contract and remain essentially stable. Therefore, any downward fluctuations in price will reflect changes in demand. During the period considered, the Construction Price Index consistently increased, but downward fluctuations in median aggregate price were experienced in 1969, 1970 and 1976 in response to decreases in regional economic growth rates and subsequent decreases in demand for aggregate.

Recent Price Levels

As noted previously, Table 11 shows the range of prices charged for a typical aggregate product, 3/4 inch sized, crushed gravel, delivered to various points in the city of Edmonton during the years 1964 to 1977. The change in the mid-range price (Column 3, Table 11) varies from year to year, decreasing in some time periods but generally increasing. A comparison of a gravel price index and an index of new construction costs shows that gravel prices have escalated at rates similar to the growth rates of local

construction costs. When aggregate prices have tended to increase at rates much in excess of those for general construction, price increases have been arrested for one or two year periods until they adjusted to similar levels. By 1968, the gravel price index had reached 164.3 while the construction cost index had increased only to 111.2 from the same 100.0 base in 1964. Price decreases in 1969 and 1970 reduced the disparity to the point where the gravel price index was 133.6 and the construction cost index was 121.9. By 1974, the indices were 214.3 and 219.9 respectively. A major increase in price resulted in indices of 330.0 and 261.3 in 1975 but a decrease in price in 1976 brought the index levels closer together again: 305.0 versus 312.9. The years during which aggregate prices decrease correspond to periods during which construction expenditures slowed in growth or dropped, as in 1969 and 1970, and 1976.[19] The fluctuations in price growth are a response to changes in demand rather than a response to changes in actual reserve availability or tenor as the availability or quality of sources of supply changed little during that period.

Table 12 compares changes in typical delivered and pit location prices during the 1975 to 1978 period. While pit prices have excalated over 60 percent during the period, delivered prices have, on the whole, decreased. Since, as shown in Chapter IV, 85 percent of aggregate production costs are made up of labor and operating costs, both of which move readily with general price levels which have

increased by over 27 percent since 1975, about half of the pit price increase is accounted for by general price level movements. The other nearly 56 percent has resulted from price increases specific to the construction industry and includes a reflection of the higher demand levels that have existed in the region. Loading and hauling costs increased by 16 percent (for a typical 6 mile haul) during the 1975 to 1978 period but appear to have been offset by cost reduction measures such as the use of larger trucking equipment in hauling operations and by price cuts resulting from heightened competition.

The costs of meeting more significant environmental regulations may increase costs somewhat in the future but these are not of a significant magnitude compared to increases resulting from transportation cost increases. As indicated in "World Resources" the:

> cost of environmental requirements, the expense of noise and dust pollution, safety and recovery or reinstatement of land will vary...The cost can be anything up to 15% of production costs when producing crushed aggregates near a conurbation.[20]

Supply Elasticity

We have seen that stability characterizes the supply function of aggregates. In contrast, demand is much less stable, shifting in response to changes in the rate of

regional growth. Accordingly, these conditions permit an attempt at estimating the price elasticity of aggregate supply.

The basic data for the measurement is given in Table 13. Regrettably, complete data can be assembled for only a four year period from 1973 to 1976, owing to the lack of a longer time series on aggregate consumption. The equation used was:

$$\dot{q}a = \alpha + B\left(\frac{\dot{P}a}{Pq}\right) + E$$

where: $\dot{q}a$ is the percentage change in aggregate consumption:

Pa, Pq are indexes of the price of aggregate and the general price level, respectively.

Therefore, $\left(\frac{\dot{P}a}{Pq}\right)$ is the change in the real price of aggregates. The following results were obtained from an ordinary least squares regression.

$$\dot{q}a = -2.525 + 0.418\left(\frac{\dot{P}a}{Pq}\right)$$

t=0.496

Correlation coefficient=0.331

The population variance of the regression is 3.55 and used in conjunction with the estimate, provides a 95 percent confidence interval estimate for the slope coefficient of

0.020 to 0.816.

Though the R^2 is low, the coefficient of real price has the correct sign. Obviously, however, the short time period contained in the regression precludes its use as an acceptable measure of supply elasticity over the long-term forecast period of this study.

Edmonton Prices Versus Prices in Aggregate Deficient Areas

To provide some insight into what aggregate prices might be if supplies were much less plentiful, prices in areas where supplies are scarce were examined.

A number of regions have been identified by the United States' Highway Research Board as being aggregate poor. The Board states that the:

> greatest shortages of naturally occurring aggregates exist in the Mid-Continent Region and the Southeastern Coastal sections of the United States. The severest shortages are found in areas along the Gulf Coast...To some extent the shortages have been offset by better exploration methods and greater emphasize on surveys of new natural aggregate sources.[21]

Table 14 lists the prices of several typical aggregate products in Edmonton and in several regions of the United States, including some considered to be "aggregate-poor", as determined by a City of Edmonton survey.

Only two of the locations which replied actually indicated a supply shortage. Norfolk, Virginia must use lower grade materials imported from locations 250 miles away and Cedar Rapids, Iowa is experiencing a shortage of coarser materials. Many correspondents did indicate that supplies of good materials were dwindling and environmental regulations were cited as being a contributing factor to supply difficulties. While Edmonton prices ranged from significantly less than the mid-range prices for the products shown to 4.4 percent above; prices in Norfolk and Cedar Rapids ranged to as high as 39.5 percent higher than the mid-range prices. If this limited data can be taken as an indication, depletion of reserves could result in aggregate product prices as much as 140 percent higher than those in regions with adequate reserves. Basic aggregate costs for an average home would then rise from $1500 to $2100 or account for 5.6 percent rather than 4 percent of the basic construction cost of a house. The price of the house would increase by 1.7 percent. The cost of a mile of roadway, using 60,000 tons of aggregate, would increase by a significant 11.7 percent.

TABLE 11

PRICE OF 3/4 INCH SIZE CRUSHED GRAVEL

(1964-1977)

Year	Range	Median	Change From Previous Year (%)	Gravel Price Index 1964=100	Const'n Cost Index 1964=100
1964	1.31-1.47	1.40	----	100.0	100.0
1965	1.80	1.80	28.6	128.6	100.8
1966	1.98-2.05	2.02	12.2	144.3	102.3
1967	2.05-2.15	2.10	4.0	150.0	106.9
1968	2.30	2.30	9.5	164.3	111.2
1969	2.12	2.12	7.8	151.4	115.7
1970	1.87	1.87	-11.8	133.6	121.9
1971	2.05-2.30	2.18	16.6	155.7	127.3
1972	2.13-2.40	2.26	3.7	161.4	138.9
1973	2.50-2.75	2.62	15.9	187.1	168.8
1974	3.00	3.00	14.5	214.3	219.9

TABLE 11--Continued

Year	Range	Median	Change From Previous Year (%)	Gravel Price Index 1964=100	Const'n Cost Index 1964=100
1975	4.15-5.10	4.62	54.0	330.0	261.3
1976	4.10-4.44	4.27	-7.6	305.0	312.9
1977	3.78-5.00	4.39	2.8	313.6	341.1

Source: City of Edmonton. Unpublished data from files.

TABLE 12

CHANGES IN DELIVERED AND PIT PRICES OF AGGREGATE

(1975-1978)

Year	Delivered Price			Price at Pit		
	Price Range	Median	Gravel Price Index	Price Range	Median	Gravel Price Index
1975	4.15-5.10	4.62	100.0	1.85-2.10	1.98	100.0
1976	4.10-4.44	4.27	92.4	1.85-2.10	1.98	100.0
1977	3.78-5.00	4.39	95.0	2.35-2.60	2.48	125.3
1978	4.07-4.58	4.32	93.5	3.00-3.40	3.20	161.6

Source: City of Edmonton. Unpublished file data on materials costs, 1978. Steel Brothers Canada Ltd., Edmonton. Price Lists, 1978.

TABLE 13

PRICE ELASTICITY DATA

Parameter	Year			
	1973	1974	1975	1976
Actual Gravel Price	$2.62	$3.00	$4.62	$4.27
Indexed Gravel Price	$2.37	$2.45	$3.40	$2.91
Regional Aggregate Consumption (1000's of tons)	9,540	9,940	10,028	9,747
Consumer Price Index (CPI) (1971=100)	110.6	122.5	135.8	146.7
Percent Change: Actual Price / CPI from previous year	+8.9	+3.4	+38.9	-14.4
Percent Change in Consumption from previous year	+3.0	+4.2	+0.9	-2.8

Source: Table 9, and D. Pridy, Edmonton Regional Aggregate Study, Report prepared for City of Edmonton, Engineering Department, July, 1978.

TABLE 14

COMPARISON OF AGGREGATE PRICES IN NORTH AMERICA

(Fall, 1977)

Municipality	Product			
	Portland Cement Concrete (Del'd)	Asphaltic Cement Concrete	Road Stone (Limestone)	Crushed Gravel
Edmonton	$32.00	$13.75		$3.8-5
Huntington, W.V.	33.40	20.00		5.45
Cedar Rapids, Iowa			$2.60	6.00
Jacksonville, Fla.	29.25	17.75		
Denver, Colo.	32.35	15.00		6.16
Los Angeles, Cal.	30.00	13.00		5.10
Cincinatti, Ohio	33.20	14.00		2.67
Norfolk, Va.	36.00	23.00	7.50	
Des Moine, Iowa			3.25	4.50

TABLE 14--Continued

Municipality	Product			
	Portland Cement Concrete (Del'd)	Asphaltic Cement Concrete	Road Stone (Limestone)	Crushed Gravel
Buffalo, N.Y.			8-12	5.00
Miami Beach, Fla.		19.00	2.00	2.50
Minneapolis, Minn.	29.05	10.00	7.50	
Tampa, Fla.	25.29	18-21.5		
Range	25.3-36	10.-23	2.-12.	2.5-6.2
Mid-Range	\$30.64	\$16.50	\$7.00	4.35

Source: City of Edmonton. Results of unpublished survey conducted by Engineering Department.

CHAPTER IV

REVIEW OF AGGREGATE USAGE PREDICTION MODELS

Other studies which have predicted future aggregate usage were referred to in determining the approach to be followed in formulating a prediction model for this study.

Several studies of this type have been conducted elsewhere in past years and they are examined in this chapter. The most notable were two conducted previously in Canada. The first of the two, the Mineral Aggregate Study of the Central Ontario Planning Region[22], was prepared for the Ontario Ministry of Natural Resources by Proctor and Redfern Limited, completed in March, 1974. Work in Ontario has since continued toward developing a reasonable mineral management program for the heavily populated Central Ontario region. The second study, completed in June, 1976, by the UMA Group: Aggregate Resources of the Winnipeg Region[23] was prepared for the Manitoba Department of Mines, Resources and

Environmental Management.

Figures 9, 10 and 11 are schematic diagrams of the steps employed in preparing projections of aggregate usage in the Ontario, Manitoba and this, Alberta, study respectively. The methods employ elements which are similar, and in some cases identical, in nature. Each starts with a projection of population which is then related to some measure of economic activity in the study area.

Central Ontario Planning Region Model

The model used in the Central Ontario Region started with projections of: (i) provincial population and (ii) per capita income. The product of the population and provincial per capita income projections was a projection of potential Gross Provincial Product with the construction share based on historical experience. This yielded an estimate of total construction in the Province of Ontario.

Based on the relative population of the region and its growth rate compared to the province's, annual spending on construction in the Central Ontario Region was then derived from the provincial data. The proportion of the region's past spending in the residential, non-residential and engineering sectors was utilized to determine annual spending in each sector. The dollar values within each sector were then multiplied by factors accounting for the

typical quantity of aggregate used, per constant 1971 dollar spent on construction in a particular sector, to determine total annual and cumulative usage of aggregate to the year 2001.

Winnipeg Region Model

A linear regression was used to relate spending on construction in Manitoba and the number of households present in the province. A projection of Manitoba population, coupled with household formation trend predictions, was employed to obtain a prediction of annual provincial construction spending. Historical data on spending in different construction sectors; residential, non-residential, road, and other engineering, was used to separate provincial data into sectors and past data on the proportion of each sector's spending which had taken place in the Winnipeg region allowed estimation of Winnipeg's share of sectoral spending. As a final step, aggregate input factors were applied to the spending estimates to determine aggregate usage in the area to the year 1996 with an extrapolation made to 2026. An alternate forecast based on a different population growth trend and a separate analysis of high quality aggregate usage rates were provided.

Central Alberta Region Model

The Alberta study started with a linear regression relating total building and engineering construction spending in Alberta with the absolute number of households present in the province. This was done to project provincial construction spending. Allocation to the region was made by the relative number of households and by the area's growth rate relative to that of the province. Initial proportions were based on the number of households in the study region to the number of households in Alberta in 1977. The growth rate of numbers of households was different for the region than it was for the province as a whole, so allocations in subsequent years were based on the ratio of households predicted to exist in the future year under consideration. Historical data on the proportion of construction spending input into each of the building, road and "other" construction sectors was used to determine sector spending in Central Alberta. Aggregate input factors in tons per dollar were used to obtain tonnages of material used in the region. The usage was further allocated between sand, gravel and high quality materials. The results of the application of this model to the Central Alberta region are given in Chapter V.

The Ontario model makes a number of assumptions which may make its results questionable. The model assumes that all investment funds generated in Ontario are invested in

Ontario and all funds invested in Ontario originate in Ontario. In addition, the model assumes a relationship exists between gross provincial product and investment. The use of a projection of personal income involves uncertainty in future levels as well as in means of valuation.

The Manitoba model was based on a projection of historical data on households and construction spending. However, the use of only ten years of data in obtaining a regression line, as shown in Appendix 1, could result in a serious error in the predictions.

Both the Ontario and Manitoba models are discussed in more detail in Appendix 2.

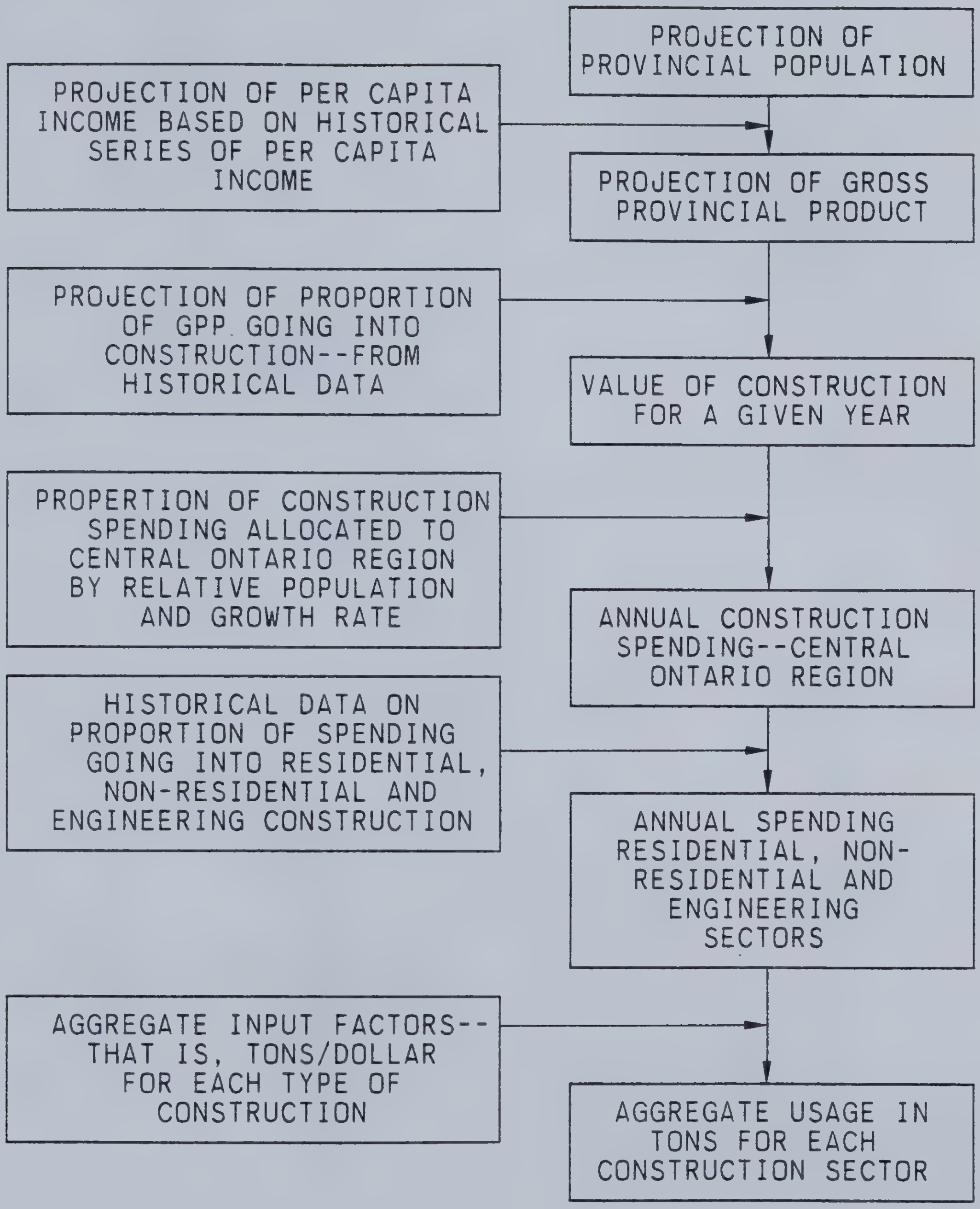

FIGURE 9

SCHEMATIC DIAGRAM - PROCTOR AND REDFERN
ONTARIO MODEL

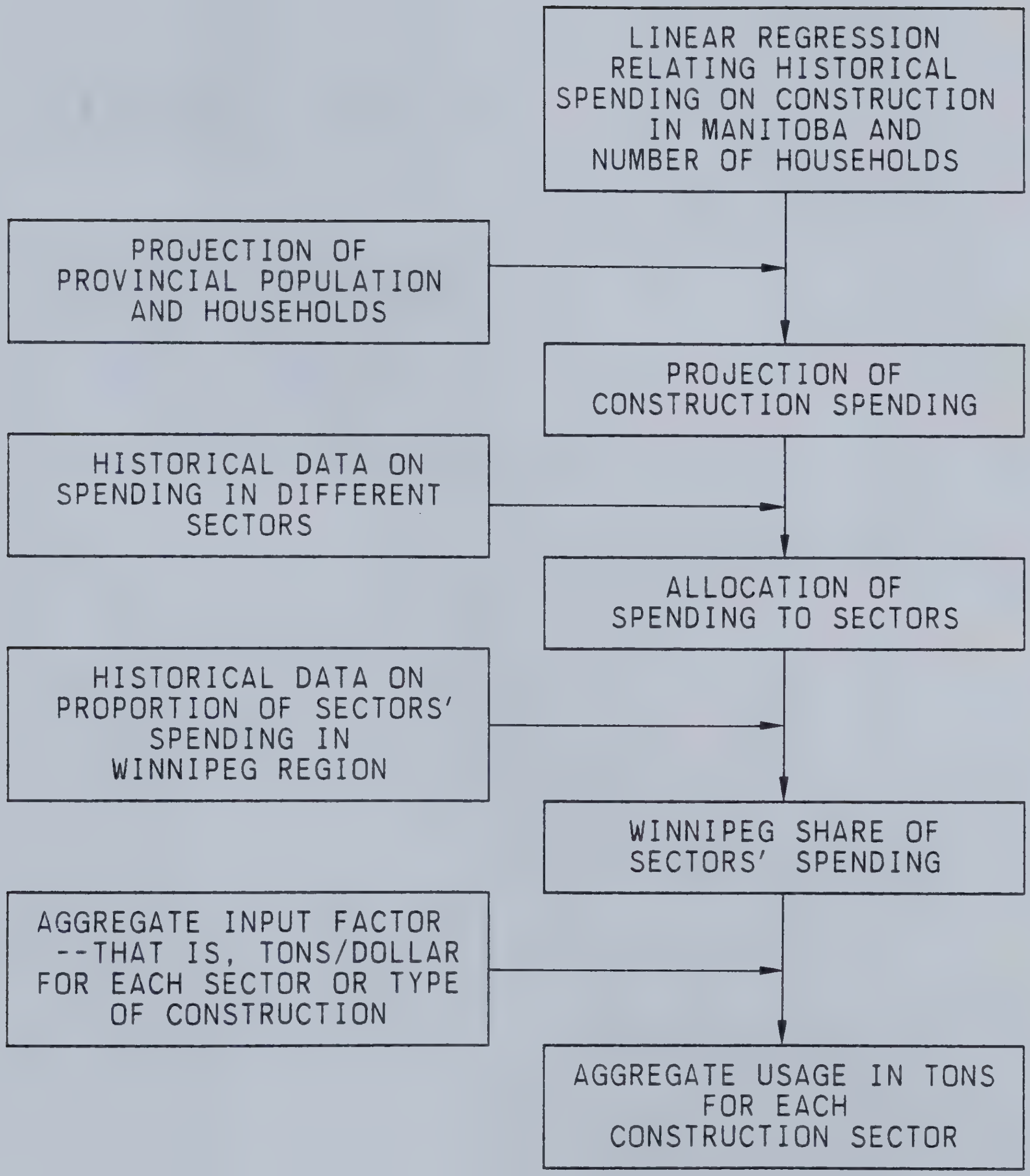

FIGURE 10

SCHEMATIC DIAGRAM -
UMA'S WINNIPEG MODEL

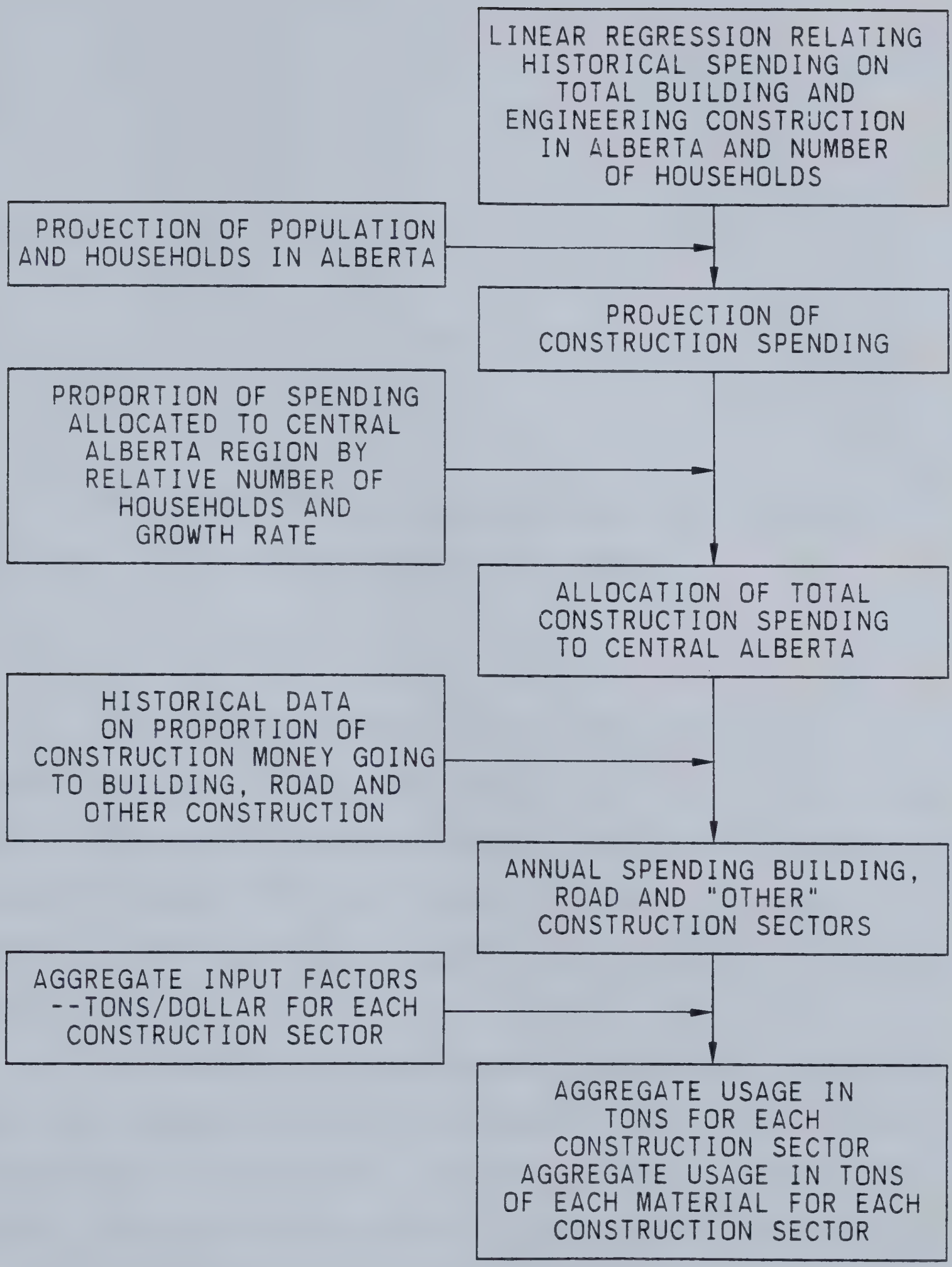

FIGURE 11

SCHEMATIC DIAGRAM -
CENTRAL ALBERTA MODEL

CHAPTER V

APPLICATION OF A PREDICTION MODEL FOR AGGREGATE USAGE IN CENTRAL ALBERTA

Having described the engineering and economic background of the aggregate industry in Chapters I, II and III and discussed prediction models for growth in aggregate usage in Chapter IV, this Chapter presents the results obtained when the Central Alberta Region Model was applied to the data.

The estimates of aggregate usage derived from using the most probable population growth rates for the region (Projection 1) are given in Tables 15 and 16. Table 15 gives the annual usage rates of sand, gravel and concrete quality materials for the years 1978 to 2007. Table 16 lists cumulative usage of these materials for the same time period. Table 17 summarizes final cumulative usage figures derived from using the most probable and several less

probable growth rates for the study region.

While the most probable prediction rate is based on low fertility rates (1.895) and medium net in-migration (7000 per annum for the Edmonton sub-region), the other three projections; 2,3 and 4 are based on low fertility, low migration (3000 per annum); medium fertility (2.173), medium migration and high fertility (2.432) and high migration (11,000 per annum) respectively. The urban population growth rate was combined with a rural growth rate estimated at 1.2 percent per annum, over the period, to arrive at an overall, regional, growth rate.

A detailed presentation of the prediction methodology is given in Appendix 1.

As shown in Table 15, total annual usage of materials, according to Projection 1, increases from 13,520,000 tons in 1978 to, nearly double, 25,950,000 tons in 2007. Cumulative usage of sand, gravel and concrete materials for the thirty year period, as given in Table 16, amounts to 69,680,000, 299,560,000 and 226,310,000 tons respectively; a total of 595,550,000 tons.

Consumption of Reserves

Table 18 is reproduced from the "Edmonton Regional Aggregate Study" and lists the engineering reserves of materials estimated to be available in the study region.

The reserve figures recorded for each municipality are restricted to those parts of the unit included in the study area.[24]

Table 19 compares usage rates, as obtained from Projection 1, with the reserves potential.

The data in Table 19 indicate that supplies of aggregate are much in excess of requirements to the Year 2007 according to Projection 1. Table 20 contains the same comparison using the projection with the highest usage rate, number 4.

Cumulative usage of material amounts to only 6.9 percent of total engineering reserves for all materials consumed in the most probable case (Projection 1) and only 7.9 percent of reserves in the maximum population growth case (Projection 4). Material usage in each category is 13.8 to 14.2 percent higher from Projection 1 to Projection 4. That is, while total aggregate usage for a final population in the study area of 1.25 million is 595.6 million tons, total usage for a final population of 1.56 million is 677.5 million tons, 81.9 million tons or 13.8 percent more. This 81.9 million ton difference, however, is only slightly less than 1 percent of total reserves of aggregate in the area. Although 81.9 million tons appears to be a significant quantity of material, it represents only 3.2 years' supply at Year 2007, Projection 1, usage rates. A more significant concern is the effect of consumption on the three major sources of aggregates.

In the case of Projection 1, only 1.3 percent of sand reserves are indicated as being consumed. Relatively more significant portions of the scarcer, more useful coarse gravel and quality materials would be consumed; 13.4 percent and 20.0 percent respectively. This means that, if the percentage growth rates for aggregate usage as obtained in Projection 1 are maintained for succeeding 30 year periods, known engineering reserves of high quality coarse materials, that is, those within only the study area, would run out in 72 years (in 2050) and regular quality coarse aggregate would run out 15 years later in 2065. Projections 1 through 4 resulted in projected per capita usage rates of the magnitude of 20.6 tons per annum by 2007. If per capita usage is 25 or 50 percent higher, or 25.8 and 30.9 tons per capita, for each year in the 30 year period, Projection 1 usage would be 744.5 and 893.4 million tons respectively. If the same proportions of the different types and qualities of materials are used, then, when per capita usage was 25 percent higher, quality materials will run out by 2050 and glacial and recent gravel by 2065. If per capita usage is 30.9 tons by 2007 or 50 percent higher, quality materials will be exhausted by year 2050 and other gravel by 2060.

At the most probable of expected population growth rates, conventional and quality materials in the study region will deplete by Year 2050 and regular gravels by 2065. A 25 percent higher population growth rate will exhaust known reserves three years earlier while a 25

percent increase in per capita usage will have the same effect as a 25 percent higher population growth rate. A 50 percent higher per capita usage will reduce reserves by from 5 to 10 years' supply.

The discussion of reserves presented in this section, as an indicator of the longevity of reserves, appears to imply that significant sources of aggregate do not exist outside the boundary of the study area. In reality, and as indicated previously, as nearby sources deplete and the relative price of aggregate increases, the study area boundary recedes as aggregate will be brought in from areas outside the boundary. The fact that reserves of a given type are indicated as being depleted 65 or 80 years in the future does not mean that all construction will grind to a halt, never to resume. The foregoing is included only to give the reader a feel for the life of reserves within a defined area. In short, the Central Alberta study area, as outlined in Figure 1, is significant only as a delimiter of a geographic area of interest for the purpose of this thesis.

Although materials will be available for many decades to come it will be the more valuable coarser materials which will deplete first.

Conservation--A Complicating Factor

The means by which supplies increase makes it difficult to induce conservation of aggregate materials. Although prices increase, engineering reserves never deplete and as was indicated by Francis:[25]

> The purer a deposit, the lower is the technology of processing, the lower the energy requirement and therefore the lower the cost of exploitation. These factors lead towards a reduction in reserves by encouraging demand, and whilst reducing the likelihood of conservation they are the very factors which should raise concern about the need to conserve. When minerals are extracted from less pure deposits, a higher processing technology is needed, together with a higher energy requirement, and this has the effect of increasing reserves, and reducing demand and the need for conservation.

Reduction of Reserves by Other Factors

The data referred to in the previous section assumes that the reserves are reduced only by consumption as building materials. A potential problem in making that assumption is illustrated in this comment made during a 1975 conference on the conservation of world resources:

> As far as long range planning is concerned, with construction aggregates the key to their use is their close proximity to the consumer. This always gives rise to areas of conflict with regard to land use and

> environmental aspects, noise and dust. In many cases too it is found that unless long-range planning is properly considered, the deposits become covered. Once a city, a park or a monument has been built over an area, that area is lost. In Denver, Colorado, in the period 1935-67, some 900 Mt of reserves were reduced to 100 Mt due to urban encroachment.[26]

Land use conflicts can result in the removal of potential deposits of sand or gravel from possible exploitation. As was the case in Denver, the expansion of cities and rural residential properties can have a devastating effect on the availability of reserves which are close to an urban center. However, it is not only land that becomes physically covered by buildings, street and other urban paraphernalia which is sterilized in terms of aggregate production. Residents have demonstrated an unwillíngness to put up with the noise and dust generated by extraction operations anywhere in the vicinity. According to one study, while 81 percent of property owners would object to a pit being located 0.5 to 1.0 miles away, over one quarter of the same property owners would still object to having gravel extraction operations over 2 miles away from their homes.[27] The effect of these kinds of objections is to make gravel extraction operations an objectionable land use for some distance away from urban or country residential locations. The possible removal of reserves because of such conflicting uses led to the inclusion of Chapter VI which considers the effects of current and future land use zoning regulations on aggregate reserves.

TABLE 15

PROJECTED ANNUAL USAGE OF AGGREGATES

-PROJECTION 1

(1978-2007)

Year	Prov'l Growth Rate	C.Alta. Growth Rate	Annual Aggregate Usage (1000's of Short Tons)			
			Total Sand Usage	Total Gravel Usage	Quality Materials Usage	Total Aggregate Usage
1978	0.024	0.022	1582	6802	5139	13523
1979	0.024	0.022	1647	7082	5350	14079
1980	0.024	0.022	1706	7333	5540	14579
1981	0.024	0.022	1762	7577	5724	16063
1982	0.023	0.020	1815	7801	5894	15509
1983	0.023	0.020	1867	8025	6063	15954
1984	0.023	0.020	1919	8250	6232	16401
1985	0.023	0.020	1972	8476	6403	16851
1986	0.023	0.012	2009	8637	6525	17172
1987	0.021	0.018	2058	8846	6683	17586

TABLE 15--Continued

Year	Prov'l Growth Rate	C.Alta. Growth Rate	Annual Aggregate Usage (1000's of Short Tons)			
			Total Sand Usage	Total Gravel Usage	Quality Materials Usage	Total Aggregate Usage
1988	0.021	0.018	2106	9056	6842	18004
1989	0.021	0.018	2156	9270	7003	18428
1990	0.021	0.018	2206	9486	7166	18858
1991	0.021	0.018	2257	9704	7331	19293
1992	0.018	0.016	2304	9904	7482	19690
1993	0.018	0.016	2351	10106	7635	20092
1994	0.018	0.016	2398	10311	7790	20499
1995	0.018	0.016	2447	10518	7946	20911
1996	0.018	0.016	2496	10729	8105	21330
1997	0.017	0.015	2542	10926	8254	21722
1998	0.017	0.015	2588	11126	8406	22120
1999	0.017	0.015	2635	11329	8559	22524
2000	0.017	0.015	2683	11535	8714	22932

TABLE 15--Continued

Year	Prov'l Growth Rate	C.Alta. Growth Rate	Annual Aggregate Usage (1000's of Short Tons)			
			Total Sand Usage	Total Gravel Usage	Quality Materials Usage	Total Aggregate Usage
2001	0.017	0.015	2732	11743	8871	23346
2002	0.017	0.015	2781	11954	9031	23765
2003	0.017	0.015	2830	12168	9192	24191
2004	0.017	0.015	2881	12385	9356	24622
2005	0.017	0.015	2932	12604	9522	25059
2006	0.017	0.015	2984	12827	9691	25502
2007	0.017	0.015	3036	13053	9861	25951

TABLE 16

CUMULATIVE USAGE OF AGGREGATES

-PROJECTION 1

(1978-2007)

Year	Cumulative Usage (1000's of Short Tons)			
	Sand	Gravel	Quality Material	Total of All Materials
1978	1582	6802	5139	13523
1979	3229	13884	10489	27602
1980	4935	21217	16029	42181
1981	6698	28794	21753	57244
1982	8512	36595	27646	72753
1983	10379	44260	33709	88707
1984	12298	52869	39941	105108
1985	14269	61345	46344	121958

TABLE 16--Continued

Year	Cumulative Usage (1000's of Short Tons)			
	Sand	Gravel	Quality Material	Total of All Materials
1986	16278	69982	52869	139130
1987	18336	78829	59552	156716
1988	20442	87884	66394	174720
1989	22598	97154	73396	193148
1990	24805	106639	80562	212006
1991	27062	116344	87894	231299
1992	29366	126248	95376	250989
1993	31716	136354	103011	271081
1994	34115	146664	110800	291580
1995	36561	157183	118746	312491
1996	39057	167912	126852	333820
1997	41598	178838	135106	355543
1998	44187	189964	143512	377663
1999	46822	201294	152071	400186
2000	49505	212828	160785	423118

TABLE 16--Continued

Year	Cumulative Usage (1000's of Short Tons)			
	Sand	Gravel	Quality Material	Total of All Materials
2001	52236	224572	169656	446464
2002	55017	236526	178687	470230
2003	57847	248693	187879	494420
2004	60728	261078	197236	519042
2005	63660	273683	206758	544101
2006	66644	286510	216449	569602
2007	69680	299563	226310	595553

TABLE 17

SUMMARY: RESULTS OF ALTERNATE PROJECTIONS

Proj'n No.	Final Area Pop'n (1000's)	Cumulative Usage-1978/2007 (1000's of tons)				Per Capita Usage
		Sand	Gravel	Quality Materials	Total	
1	1251	69700	299600	226300	595600	20.5
2	1129	65300	280500	211900	557700	20.6
3	1342	72200	310300	234400	617000	20.6
4	1563	79300	340800	257400	677500	20.7

TABLE 18

AGGREGATE RESERVES - CENTRAL ALBERTA REGION

Municipality	Portion of Whole Mun In Study Area (%)	Mineral Resource Reserve (millions of short tons)			
		Total Sand	Gravel	Quality Aggr.	Total Aggr.
Athabasca	61.5	136.0	190.6	---	326.6
Barrhead	84.0	103.1	100.8	---	203.9
Beaver	72.2	57.1	17.1	---	74.3
Camrose	92.9	33.2	108.9	230.2	372.3
Flagstaff	9.0	18.6	---	---	18.6
Improvement District #11	7.7	---	4.6	---	4.6

TABLE 18--Continued

Municipality	Portion of Whole Mun In Study Area (%)	Mineral Resource Reserve (millions of short tons)			
		Total Sand	Gravel	Quality Aggr.	Total Aggr.
Improvement District #14	18.3	12.4	18.5	---	30.9
Improvement District #15	1.2	---	32.5	---	32.5
Improvement District #18	0.3	8.1	2.2	---	10.3
Lacombe	64.3	219.9	212.0	68.2	500.1
Lac Ste Anne	85.3	183.9	211.5	34.4	429.8
Lamont	100.0	430.0	90.5	---	521.4
Leduc	100.0	138.2	119.0	---	257.2
Minburn	67.6	36.8	7.7	---	44.5
Parkland	97.0	1090.	243.9	232.7	1566.7
Ponoka	95.0	363.3	216.9	229.3	809.5

TABLE 18--Continued

Municipality	Portion of Whole Mun In Study Area (%)	Mineral Resource Reserve (millions of short tons)			
		Total Sand	Gravel	Quality Aggr.	Total Aggr.
Smoky Lake	51.7	161.3	119.9	---	281.2
Strathcona	100.0	358.7	202.7	---	541.4
Sturgeon	100.0	625.7	113.4	---	990.3
Thorhild	100.0	98.8	17.4	---	116.2
Two Hills	61.5	66.0	23.7	---	89.7
Westlock	94.3	392.0	47.1	---	439.1
Wetaskiwin	97.1	725.7	133.7	80.6	940.0
Total		5239.8	2234.7	1126.6	8601.1

Source: D. Pridy, Edmonton Regional Aggregate Study Report prepared for City of Edmonton, Engineering Department, July, 1978.

TABLE 19

AGGREGATE USAGE VERSUS RESERVES

TO YEAR 2007-

PROJECTION 1

	Mineral Resource Reserve (millions of short tons)			
	Sand	Gravel	Quality Material	Total
Reserves	5240	2230	1130	8600
Cumulative Usage to Year 2007	69.7	299.6	226.3	595.6
% Consumed	1.3	13.4	20.0	6.9

TABLE 20

AGGREGATE USAGE VERSUS RESERVES

TO YEAR 2007-

PROJECTION 4

	Mineral Resource Reserve (millions of short tons)			
	Sand	Gravel	Quality Material	Total
Reserves	5240	2230	1130	8601
Cumulative Usage to Year 2007	79.3	340.8	257.4	677.5
% Consumed	1.5	15.3	22.8	7.9

CHAPTER VI

LAND USE ZONING AND AGGREGATE RESERVES

The study results presented in Chapter V indicate that Central Alberta will actually use a relatively small proportion of its mineral aggregates by 2007. However, removal of aggregate bearing lands from the mining market can take place when urbanization occurs on the surface of lands bearing reserves. This chapter examines the implication of future land uses, particularly urbanization, for stores of aggregate.

Table 21 presents data on the effect of zoning regulations on potential "engineering" reserves of aggregate. The locations of the sand and gravel deposits enumerated in the "Edmonton Regional Aggregate Study" were examined as to the zoning restrictions in effect at the location or in the absence of such regulations, the actual use ascribed to the location. The deposits were then sorted

and totalled by whether or not the land use category within which a deposit occurred would allow extraction. All tracts of land outside of the major cities and towns in the region were included in the calculations.

Only 6.5 percent of sand reserves are in areas affected by unfavorable zoning, reducing usable stores from 5234 million tons to 4896 million tons. Of particular interest is the fact that 13.2 percent of the sand reserves are in locations which, it is anticipated, the Edmonton Regional Planning Commission (ERPC) will designate as mineral resource reserve areas.[28] The intent of these reserve restrictions would be to ensure the utilization of these areas in a sequence of applications that will allow the production of the mineral resources in the land before it is used to locate buildings or roads.

River terrace deposits, for all three types of materials are divided evenly between the extractable and non-extractable categories. This is an assumption which arises because some river terrace deposits may be extracted while others may not and it was not possible to determine exactly what proportion of these aggregate deposits could be made available. However, 50 percent was determined to be a reasonable estimate based on the current approval rates for development applications.

A larger proportion of gravel deposits, 14.6 percent, are unavailable for exploitation, reducing accessible reserves from 2238 million tons to 1911 million tons.

Inaccessible river valley deposits of gravel account for 50 percent of the unavailable deposits of gravel while country residential settlement has eliminated a further 29 percent of the unavailable materials. Only 1.5 percent of this class of aggregate is protected by the proposed reserve area. The mineral resource reserve area delineated so far has been calculated to preserve deposits of high quality aggregate and aeolian sands and has not included preservation of glacial deposits. Therefore, at this point, medium quality aggregates are largely unprotected by any specific zoning restrictions.

Approximately 6.2 percent of quality aggregates have been removed from access, reducing potential supplies from 1127 to 1057 million tons. One of the main objectives of the ERPC mineral resource reserve is to protect the quality aggregates in the Edmonton region and, under present plans, 23.6 percent of these materials would be located within the protected zones.

In total, 8.5 percent of all materials have been removed from production and 11.3 percent of all materials are included in planned resource reserves.

Table 22 summarizes the total available reserves, usage and unexploitable materials quantities as of the year 2007, assuming no further deposits are eliminated by urbanization and also assuming the use of Projection 1. Accordingly, 92.3 percent, 72.9 percent and 75.0 percent of the sand, gravel and quality aggregates in the Central

Alberta study area will still be available. Approximately 85 percent of all aggregates would still be available.

If no further reduction of reserves due to urbanization occurs, aggregate reserves will still be plentiful in the area 30 years hence. Of current reserves, 8.5 percent of them are eliminated from consideration because of urban encroachment and a further 6.5 percent will be consumed by 2007. While usage rates are relatively low for this short run period, the possibility of loss of a significant amount of reserves to urbanization and other conflicting land uses is a matter that merits examination. As pointed out in Chapter V, land use conflicts can have disastrous effects on potential aggregate supplies.

Land Use Conflicts

Land use conflicts surrounding the extraction of aggregates revolve around two issues. One is the problem of industrial operations in conflict with residential land use in the vicinity of extraction sites and the restoration of pit sites. The other centres on the opportunity costs which must be considered in establishing land use regulations for the protection of sand and gravel reserves and the response of reserves to changes in real price.

Residential and Restoration Conflicts

The origin of these conflicts is explained in "World Resources" as follows:

> In past years as urban expansion encroached on mineral deposits, other deposits were developed at the periphery of the expansion and the enveloped assets were lost to the community. This loss and our current higher demands, have led to increased transportation of raw materials at overhaul costs, per ton mile, approaching one-quarter of the production cost per ton.
>
> The unplanned and heedless approach to the utilization of mineral resources in the past has created severe social and economic problems. Residential districts exist in the midst of the noise, dust and heavy traffic of quarry and pit activities. Past activities are marked by a blighted and desecrated landscape.[29]

A multitude of reasons has made people much more protective of the environment of their properties than has been the case previously. As noted, if residential development is allowed in an area, the noise, dust and traffic caused by extraction operations brings objections, even if the industry preceeded the residential development. This quandary results because:

> Engineers, motivated as they are by short term technical and commercial factors, tend to concentrate on tactical matters. This is to some extent understandable in winning of nationally abundant materials. Other materials, which may be abundant internationally but not sited in the market place or rarer materials not available in concentrated deposits, are much more susceptible to strategic influences.
>
> There is a positive need for the engineer to widen his horizons and to gain a greater appreciation of

> strategic matters. He can then seek by comment and credible representation to influence the formulation of those strategies which contribute towards better planning and utilization of resources rather than those which are sought for short term tactical reasons or political expediency.[30]

The conflicts caused by engineers and developers result from individuals and corporate entities carrying out normal development activities which, in serving their personal and corporate interests without reference to a development plan which has been approved by authorities, have the end result, unknown to them, of consuming land capable of yielding mineral resources.

These existing conflicts are of a continuing nature but are not irresolvable. Improved land use planning would eliminate basis for conflict. However, several related issues exist which have no simplistic answers.

Zoning and Reserve Conflicts

An issue of long term significance is the use of land use zoning to reserve aggregate deposit sites until the aggregate is needed.

Where this question has been considered, legislators have concluded that protection of deposits through land use regulations is a prudent course of action. The general impression in North America has been that:

> To prevent social and economic chaos, long term planning and control of large urban communities is necessary. The need to integrate a healthy and respected industrial mineral industry into the official plans is apparent.
>
> An initial requirement in planning the proper development of the community is the identification and mapping of the natural resources available...Each municipality should have a map of the mineral resources within its jurisdiction. Proper zoning regulations should make provision for a raw materials base adequate to support the present and future population of the community. Proper control of the development of these resources should prevent exhorbitant prices and, at the same time, protect the welfare of the public by ensuring that certain performance standards are met by producers. The total area of land that must be set aside for mineral development will generally be a very small proportion of the total area of the community. Judicious planning can allow these areas to be worked and, later, rehabilitated to other uses with a minimum of conflict.[31]

A need to practice conservation is indicated. This "implies an awareness of the relationship between current and anticipated needs and known reserves, with suitable allowance for possible future discoveries".[32]

Current planning horizons run to 20 and 30 years in the future[33] and for many purposes this appears to be a practical time frame. However, in the case of non-renewable resources many environmentalists believe that it might be more circumspect to consider an even longer time frame, even if as in the case of petroleum resources, the populace in general prefers to pursue more short term policies.

Population increases expected in the region are of major concern when discussing land use planning. In the most probable case, area population will increase by 493,000

or 65 percent by 2007. Where current urban areas in the region total approximately 150 square miles, a similar density of population will consume another 100 square miles. Significant amounts of quality gravel and aeolian sand deposits are located within 5 miles of the city of Edmonton. Although accounting for only a small portion of total area stores, because of their proximity to markets, greater care could be exercised in locating development if avoiding encroachment on possible extraction sites is desirable.

Of further note are country residential settlements which are located at distances farther out of the urban center. Between 1971 and 1973, of the 800 acres of rural land converted to country residential land in Alberta, some 320 acres was within the jurisdictional boundaries of the Edmonton Regional Planning Commission.[34] Since the agreed policy of the municipalities in the ERPC area has evolved to one of allowing a full spectrum of housing alternatives to be provided for the region it is to be expected that the current popularity of country residential housing will continue.[35]

Country residential development can remove from 1 to 20 acres of land from alternate land use availability per household, therefore large areas of land can be consumed very rapidly. As a result, country residential development may have to be carefully planned if it is desired to preserve the availability of nearby reserves. In areas where a high potential for usable aggregates exists,

development plans can be formulated so that urbanization occurs on land that is found to have no value for aggregate production.

Detailed studies can be conducted to confirm the location and extent of reserves needing protection and any tract of land being urbanized could be examined for aggregate deposits as a condition of development.

The opportunity costs of setting aside those lands which will be used for agricultural purposes, for an indefinite period of time, are relatively insignificant. It will be many years before agricultural land 40 or more miles out of Edmonton will be required for aggregate extraction. A 160 acre tract of agricultural land at those distances from Edmonton now sells for approximately $50,000 (1978) and once extraction is completed could be returned to agricultural use with a value of, say, no less than $40,000 (in the same dollar terms). If such a piece of land, for example, has an 80 acre area with a 1 yard thick seam of gravel in it, it will contain about 387,200 cubic yards or 523,000 tons of gravel. If the gravel royalty is 30 cents per ton, the value of the gravel is about $150,000. This assumes that the royalty payment, usually set for the 5 or 10 year length of the contract, includes a discount factor over the time period which is acceptable to the vendor. Coupled with an agricultural value of $40,000, the property is worth $190,000 and gravel extraction plus agricultural use is a profitable land use scheme. Even if the land

cannot be returned to a high grade agricultural use and has a residual value of only $30,000, aggregate extraction purposes still outweigh a purely agricultural use in economic terms, by existing economic valuation scales.

Within 20 miles of Edmonton, a quarter of land is likely to be worth $160,000 because of country residential use and speculative possibilities. For the land to be an attractive investment for gravel extraction purposes, over 500,000 tons of 30 cent per ton gravel must exist on it and the price of gravel would have to increase correspondingly to make holding such land profitable. However, compared to a 14 cent per ton charge for carrying a ton of aggregate an extra mile, a doubling or tripling of a 20 or 30 cent per ton royalty payment for gravel would be relatively insignificant. Land which is close to Edmonton and can be subdivided is worth $250,000 per quarter section and up. At 40 cents per ton, the land must contain over 600,000 tons of gravel materials to make it practical to maintain the land's availability for gravel extraction.[36]

Two, interrelated, decisions are required in the Edmonton area. Should aggregate reserves be zoned in such a way as to prevent the urbanization of the lands containing them and, if so, what proportion of reserves should be protected?

Although conservation is beneficial to industry and society (as the consumers of aggregate), there are factors which work against effective conservation.

Quality reserves have low processing costs, a condition which encourages their use. However, a price structure must exist which makes it possible to produce from the area of the geographic margin of extraction. Any additional costs such as additional transportation or processing costs relative to supplies closer to the market or of better quality must be recoverable. Therefore, given a particular level of demand, changes in the market price of aggregate will, to a large extent, be based on incremental production costs at the margin of extraction. Since the price is already near the level dictated by the margin of extraction costs, when it becomes necessary to use lower quality or more distant reserves the higher costs have little effect on short term demand because of price inelasticity, the reasons for which were discussed in Chapter III. The higher prices induce increased supplies as further processing or haulage of materials becomes economically feasible. Since supplies are increased, attention is diverted from the need to conserve.[37]

Since production and transportation costs are lower for reserves which are close to the market a surplus may be created by sales of these less expensive aggregates since prices are set relative to the cost of marginal aggregate. The beneficiaries of that surplus may be the owner of the property, who gains through higher royalty payments, or the lessee if the property was leased at a lower royalty rate. At least part of this surplus could be described as an

opportunity cost return for use of land having a higher utility than that at the production margin.

Since higher prices are so easily absorbed, aggregate supplies are limitless because aggregate can be brought in from farther and farther away as long as real aggregate price increases allow the payment of increased transportation costs.

If reserves are not protected, that is, a free market system is allowed to prevail, when it becomes opportune to develop a tract of aggregate bearing land the owner of the land gets full value for the property. If the land is zoned so that no development can take place until after the aggregate is removed, the owner loses unless the price of the aggregate is bid up to give the producer opportunity earnings equal to the effective utility of the land. That is what very likely will take place. The owner of the land will weigh alternate uses in determining the value of his property and will not allow its retention as a reserve for aggregate unless the price he eventually obtains provides a return appropriate to the maximum value of the land. If the land is expropriated, the owner has an excellent case to demand payment for the full value of the land. If the government takes ownership of the land at market value and sells aggregate at an artificially low price, then users of aggregate are essentially receiving a government subsidy.

The crux of the zoning issue is not so much a matter of exhausting the supplies available to the area as it is a

question of whether or not government is willing, or able, to subsidize aggregate users.

The definition of conservation given in a previous paragraph indicates that consideration should be given to anticipated needs. What has not been established is how far ahead those anticipated needs should be provided for. Since alternate aggregate materials will be available indefinitely, even though they may have a higher cost, some effort should be devoted to determining what level of protection if any should be given to aggregate reserves. Inflated aggregate costs will increase the capital cost of construction by only 1 or 2 percent. Will it be to Central Alberta's interest to attempt to preserve its aggregate reserves, given the administrative costs that may be involved?

In the Edmonton region, a decision must be made as to what proportion, if any, of reserves should be protected. In addition, should protected reserves be expanded to include coarse sand as well as fine sand sources? The 1.5 percent of all conventional gravel deposits now protected could be expanded to a more significant and appropriate reserve size and, further, complete protection could be established for quality materials. Since much of the area's reserves do not occur immediately adjacent to the region's urban areas, protection of deposits may simply amount to the establishing of restrictions on land that will be used for

agricultural purposes until extraction takes place and which will subsequently be returned to agricultural use. An additional, more minor, technical issue involving the use of lower quality materials for some purposes, conserving quality materials now used for those purposes, should be resolved.

> One technical problem which stands out as one studies the literature is mix specification. Engineers specify a mix which has to be met willy-nilly, and this means that a lot of material is wasted. A better way would be to study the problem and change the design so as to make better use of available materials.[38]

The cost of these conservational measures will in all likelihood be higher in the short run but the long run value to be derived may make them worthwhile in monetary and human terms.

A significant amount of effort will be required to implement a system for orderly and efficient provision of aggregates. Man has frequently experienced instances of increasing scarcity in a commodity and through his ingenuity has always come up with a substitute or replacement material, often with resultant increases in efficiency and beneficial technologies.[39]

TABLE 21

EFFECT OF LAND USE ZONING ON RESERVES

Zone Category	Zone	Mineral Resource			
		Sand	Gravel	Quality	Total
Extractable	Agricultural	3458.3	1352.1	677.6	5488.0
	Urban Reserve	104.5	58.7	4.6	167.8
	Development Control	116.6	65.1	---	181.8
	Indian Reserves	136.7	30.6	100.6	267.9
	Highway	182.6	71.8	24.9	279.3
	Industrial	10.4	4.8	---	15.3
	Unzoned	170.6	133.3	---	303.9
	Mineral Resource Reserve	691.7	33.3	249.6	974.6
	River Terrace	24.2	161.4	---	185.6

TABLE 21--Continued

Zone Category	Zone	Mineral Resource			
		Sand	Gravel	Quality	Total
Non-Extractable	Urban	17.4	35.0	9.1	61.5
	Country Residential	281.4	36.6	16.1	344.1
	Resort	14.8	93.7	44.1	152.6
	River Terrace	24.2	161.4	---	185.6
Extractable Total		4895.7	1911.1	1057.3	7864.1
%		93.5	85.4	93.8	91.5
Non-Extr. Total		337.8	326.7	69.3	733.8
%		6.5	14.6	6.2	8.5
M. Resource Reserve (%)		13.2	1.5	23.6	11.3
Total		5233.5	2237.8	1126.6	8597.9

TABLE 22

POSSIBLE RESERVES OF AGGREGATE
AS OF YEAR 2007

	Mineral Resource (millions of short tons)			
	Sand	Gravel	Quality	Total
1. Reserves as of 1977	5233.5	2237.8	1126.6	8597.9
2. Non-Extractable as of 1977	337.8	326.7	69.3	733.8
3. Extractable as of 1977	4895.7	1911.1	1057.3	7864.1
4. Usage 1977-2007 Projection #1	65.3	280.5	211.9	557.7
5. Total Remaining as of Year 2007	4830.4	1630.6	845.4	7306.4
6. Total Remaining 2007/ Reserves 1977	92.3	72.9	75.0	85.0

CHAPTER VII

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

This study found that, on the basis of current conditions, aggregate reserves are much in excess of what is required to supply the Central Alberta region until the year 2007. Cumulative usage of the materials available in the study area, for the most probable case, Projection 1, is expected to amount to only 6.9 percent of all materials and 13.4 and 20.0 percent of coarser and high quality materials respectively. Projected usage for a final area population 25 percent in excess of Projection 1 levels, or 1,563,000, is only marginally higher at 7.9 percent of all materials (Projection 4).

Approximately 8.5 percent of current reserves were found to be eliminated from consideration as reserves

because they were located where land use restrictions would prevent their extraction. However, since experience elsewhere has found that urban development can very rapidly decrease the significance of reserves in the vicinity of urban centers, there is a degree of urgency to the need for examination of the strategy to be employed in the future with respect to whether or not aggregate reserves should be protected by government action. The occasional propensity for the government to impose land use regulations or expropriate property might better be resisted in this situation.

A very real question exists as to whether the establishment and maintenance of a system of mineral aggregate reserves would be worth the cost involved. A need exists for a comprehensive study to determine more accurately: (1) what the regional reserves and distribution of different qualities of aggregate materials are, (2) what, if any, protection should be afforded aggregates, (3) what form any protection decided upon might take.

Recommendations

Based on the information gathered for this study, the following recommendations are made:

1. Since the study conducted by the City of Edmonton into

aggregate reserves, "Edmonton Regional Aggregate Study", is essentially a baseline study of reserves in the area resulting from restricted use of field data, it is recommended that further detailed study of reserves in the area be made taking full advantage of the use of the modern field analysis techniques described in Chapter II. The nature of rural development in the Edmonton area dictates that this study be given an immediate priority. The study would be funded and carried out at the Provincial level.

2. Although this study considered only the 30 year period, 1978 to 2007, it is obvious that a non-renewable resource of this type will be required after that date. A decision should be made as to how those materials should be supplied and whether or not protection of reserves from surface development should be a feature of such a plan. That is, for what future period should reserves be provided and what trade-off should be made between reserves and the prospective availability of substitute materials.

3. In addition to giving consideration to reserve protection, conservation of resources is also possible, even when those resources are still plentiful. Government attention should be turned toward investigation of possible reuse of materials and the use of substitute or lower quality materials. Review of conservation measures should be made the continuing task

of some existing government body so that measures or techniques which become feasible, either through changes in relative prices or changes in technology, do not go unnoticed or unencouraged.

4. Total aggregate reserves in the area are considerable but the proportions that are coarse (26%) and of high quality (13%) are relatively low; attention should be given to the significance of that problem and possible resolutions.

FOOTNOTES

[1]Proctor and Redfern Ltd., Mineral Aggregate Study Central Ontario Planning Region, Report prepared for Ontario Ministry of Natural Resources (Toronto, Ontario: March, 1974) p. 2-1.

[2]"Rough Road for Sand and Gravel?" The Financial Post. May 7, 1977, p. C-2.

[3]Map adapted from: D. Pridy, Edmonton Regional Aggregate Study, Report prepared for City of Edmonton, Engineering Department, December, 1978, p. 3.

[4]D. Pridy, Edmonton Aggregate

[5]City of Edmonton, A Monitoring Report on the Edmonton Population Projections, Report prepared by the Planning Department (Edmonton, Alberta: 1977). Alberta Bureau of Statistics, Alberta Statistical Review Annual-1976 (Edmonton, Alberta; August, 1977) pp. 6-7.

[6]R.A. MacPherson and C.P. Kathol, Sand and Gravel Resources of the Edmonton Area, Alberta, Alberta Research Report 73-2 (Edmonton, Alberta: 1973) p. 4

[7]Underwood McLellan and Associates Limited, Aggregate Resources of the Winnipeg Region, Report prepared for Manitoba Department of Mines (Winnipeg, Manitoba; June, 1976)

[8]Source: Underwood McLellan, Aggregate Resources Winnipeg, plate B-1.

[9]Ibid., p. 2.

[10]Obtained from surveys of aggregate consumption in the area conducted by the City of Edmonton and the author.

[11]Statistics Canada, 1971 Census of Canada, Occupations, Catalogue 94-715 Vol. III. (Ottawa: December, 1976)

[12]Ron J. Miller, A Study of Sand and Gravel Disposition in Alberta. A report for the Economics Division, Alberta Department of Agriculture in cooperation with Lands Division, Alberta Department of Lands and Forests, April, 1972.

[13]Statistics Canada, Canada's Mineral Production - Preliminary Estimate, 1977, Catalogue 26-202, Jan., 1978.

[14]Derived from a survey of aggregate producers and purchasers.

[15]Source: Government of Alberta, Energy and Natural Resources Department, Public Lands Division.

[16]Pridy, Edmonton Aggregate

[17]Ibid.

[18]American Society of Civil Engineers (ASCE) and the Institution of Civil Engineers (I.C.E.), Proceedings of the Third Joint Conference, World Resources - Engineering Solutions (London: The Institution of Civil Engineers, 1976), p. 145.

[19]Statistics Canada, Construction in Canada, Catalogue 64-201, Various years.

[20]ASCE and ICE, World Resources, P. 160.

[21]National Research Council of Canada. Associate

Committee on Geotechnical Research. Technical Memorandum No. 95. Report in the Geotechnical Sciences to the Solid-Earth Science Study Group of the Science Council of Canada. (Ottawa: June, 1969) pp. 28-35

[22]Proctor and Redfern Limited, Mineral Aggregate Study

[23]Underwood McLellan, Aggregate Resources

[24]As shown in Table 18, the portion of the municipalities which may have been included ranges from 0.3 to 100 percent.

[25]ASCE and ICE, World Resources, p. 160.

[26]Ibid., p. 150.

[27]G.R. Shelley and Associates Ltd., Villeneuve Area Gravel Development and Reclamation Study, Report prepared for Alberta Environment (Edmonton, Alberta: March, 1977) p. 147.

[28]Edmonton Regional Planning Commission, Position Paper No. 2, Sand, Gravel and Clay Policy Summary of Objectives and Policies (Edmonton, Alberta: Jan., 1978).

[29]ASCE and ICE. World Resources. p. 144

[30]National Research Council. Report on the Geotechnical Sciences. pp. 144-145

[31]ASCE and ICE, World Resources. p. 135

[32]Ibid., p. 160

[33]Edmonton Regional Planning Commission, interviews with selected Planners.

[34]Shelley, Villeneuve Area, p. 109

[35]Edmonton Regional Planning Commission, A Choice of Growth Management Strategies (Edmonton, Alberta, February, 1977)

[36]Source of land value data: A. Teha, Kenlo Real Estate Ltd.

[37]ASCE and ICE, World Resources. p. 160.

[38]Ibid., p. 151.

[39]W. Phillip Gramm, Microeconomic Analysis of Issues in Business, Government and Society, (Toronto: McGraw Hill, 1978), Adapted from and reprinted with permission of the Wall Street Journal.

[40]Statistics Canada, 1971 Census of Canada, Households, Catalogue 93-702, Vol. II (Ottawa: May, 1973)

[41] Canadian Statistical Review, derived from Statistics Canada data, Catalogue 11-003. Canada Year Book, Statistics Canada, Information Division, 1974. Province of Alberta, Municipal Affairs Department, Population, 1971-1977.

[42]City of Edmonton, Planning Department Report on Edmonton Population Projections

[43]Edmonton Regional Planning Commission, Population of Rural Enumeration Areas for ERPC Area 1966 and 1971, Derived from Statistics Canada Census data.

[44]Alberta Government, "Population Projections for Alberta, 1976-2001", Alberta Statistical Review, 1976, p. 6-7.

[45]Statistics Canada, Population-Winnipeg, Catalogue

92-806. Statistics Canada, Canadian Statistical Review, Catalogue 11-003. Statistics Canada, Canada Year Book, 1974.

[46]Statistics Canada, Household Heads-Edmonton 1971, Catalogue 93-707. Vol. II-Part 1, September, 1974. Statistics Canada, Population by Years of Age for Census Metropolitan Areas, Catalogue 92-716, Vol. 1, Part 2, April, 1973.

[47]City of Edmonton, Engineering Department unpublished information from civic contract records. Government of Alberta, Transportation Department, Annual reports and unpublished contract information from Department records.

[48]Proctor and Redfern Ltd., Mineral Aggregate Study, pp. 4-3, 4-4. Underwood McLellan, Aggregate Resources, pp. 9,11,12,21.

[49]Statistics Canada, Construction in Canada, Catalogue 64-201, Various Years.

[50]Statistics Canada, New Housing Construction Index, Catalogue 62-008. Statistics Canada, New Housing Price Indexes, Catalogue 62-002. Statistics Canada, Housing Cost Index, Catalogue 62-010. Statistics Canada, Consumer Price Index, Catalogue 62-001.

[51]Underwood McLellan, Aggregate Resources, p. A-9

[52]Statistics Canada, Average Weekly Earnings-Unadjusted for Seasons, Catalogue 72-002. Industrial Composite for Urban Areas.

[53]County of Lac Ste. Anne No. 28, Ownership Map, Sangudo, Alberta: Jan. 1975. Prepared by Torchinsky Consulting Ltd.; County of Leduc No. 25, Ownership Map, Leduc, Alberta: Jan. 1977, Compiled by Stewart, Weir, Stewart Watson, Heinrichs and Dixon; County of Parkland No. 31 Ownership Map Stony Plain, Alberta: Jan., 1977. Compiled and drawn by Public Works Department, County of Parkland; County of Wetaskiwin No. 10, Development Control Bylaw, Map #1. Battle River Regional Planning Commission; Municipal District of Sturgeon, No. 90; Ownership Map. Morinville, Alberta Jan., 1977. Compiled by Stewart et. al.; County of Strathcona No. 28, Sherwood Park, Alberta: July 1976. Compiled by Stewart et. al.; County 30 Lamont, Zoning Bylaw No. 153. Lamont, Alberta: July, 1974, Prepared by the Provincial Planning Branch, Albertà Municipal Affairs; County 21 Two Hills, Zoning Map Two Hills, Alberta: July, 1974. Prepared by Provincial Planning Branch; Municipal District of Westlock No. 92, Zoning Bylaw No. 7-1973, Zoning Map. Westlock, Alberta: Aug. 1, 1973. Prepared by Provincial Planning Branch. County 12 Athabasca, Zoning Bylaw No. 10-197. Zoning Map. Athabasca, Alberta: Sept. 30, 1975. Prepared by Provincial Planning Branch; County of Minburn No. 27, Zoning Map. Minburn, Alberta; County of Ponoka No. 3, Development Control Bylaw 5-70-DC. Resolution No. 5; County of Camrose No. 22 Zoning Bylaws No's. 223 (Zoning Map), 373, 403 and 467. County of Beaver No. 9, Bylaw #430. Ryley, Alberta. Prepared by Provincial

Planning Branch.

[54]Proctor and Redfern Ltd., Mineral Aggregate Study, p. B-1.

[55]Ibid.

[56]Underwood McLellan. Aggregate Resources

[57]Ibid., p. A-9.

[58]The Public Lands Act. The Clay, Marl, Sand and Gravel Regulation 78/66. D.C. 297/66.

[59]The Clay and Marl Act, Revised Statutes of Alberta, 1970. ch. 50. The Sand and Gravel Act, Revised Statutes of Alberta, 1970. ch. 328.

[60]The Clean Air Act, Revised Statutes of Alberta, 1971. ch. 16

[61]The Clean Water Act, Revised Statutes of Alberta, 1971. ch. 17

[62]The Coal Mines Safety Act. Revised Statutes of Alberta, 1974. ch. 18

[63]The Department of the Environment Act. Revised Statues of Alberta, 1971. ch. 24

[64]The Environmental Council Act. Revised Statutes of Alberta, 1970. ch. 125

[65]The Land Surface Conservation and Reclamation Act, Revised Statutes of Alberta, 1973. ch. 34

[66]The Mines and Minerals Act, Revised Statutes of Alberta, 1970. ch. 238

[67]The Municipal Government Act, Revised Statutes of ALberta, 1970. ch. 240

[68]The Public Health Act. Revised Statutes of Alberta, 1970. ch. 294

[69]The Public Lands Act. Revised Statutes of Alberta, 1970. ch. 297

[70]The Soil Conservation Act. Revised Statutes of Alberta, 1970. ch. 348

[71]The Surface Rights Act. Revised Statutes of Alberta, 1972. ch. 91

[72] The Water Resources Act. Revised Statutes of Alberta, 1970. ch. 388.

SELECTED BIBLIOGRAPHY

Books and Articles

American Society of Civil Engineers and the Institution of Civil Engineers. Proceedings of the Third Joint Conference. World Resources-Engineering Solutions. London: The Institution of Civil Engineers, 1976.

City of Edmonton. A Monitoring Report on the Edmonton Population Projections. Report prepared by the City of Edmonton, Planning Department, Edmonton, Alberta, 1977.

Edmonton Regional Planning Commission. A Choice of Growth Management Strategies. Edmonton, Alberta: February, 1977.

Edmonton Regional Planning Commission. Population of Rural Enumeration Areas for ERPC Area 1966 and 1971. Derived from Statistics Canada data.

Edmonton Regional Planning Commission. Sand, Gravel and Clay Policy Summary of Objectives and Policies. Position Paper No. 2, Edmonton, Alberta, Jan., 1978.

The Financial Post Survey of Markets 1977/78. Toronto: MacLean-Hunter Limited, 1977.

MacPherson, R.A. and Kathol, C.P. Sand and Gravel Resources of the Edmonton Area, Alberta. Alberta Research, Report 73-2, Edmonton, Alberta, 1973.

Medford, R.D. Some remarks on the application of technological forecasting. Programme Analysis Unit, Chilton, Didcot, 1968, PAU M6 as reproduced in American Society of Civil Engineers and the Institution of Civil Engineers. Proceedings of the Third Joint Conference. World Resources-Engineering Solutions. London, The Institute of Civil Engineers, 1976.

National Research Council of Canada. Associate Committee on Geotechnical Research. Report on the Geotechnical Sciences to the Solid-Earth Science Study Group of the Science Council of Canada. Technical Memorandum No. 95, Ottawa, June, 1969.

Pridy, Don. Edmonton Regional Aggregate Study. Report prepared for City of Edmonton, Engineering Department, Edmonton, Alberta, December, 1978.

Proctor and Redfern Limited. Mineral Aggregate Study Central Ontario Planning Region. Report prepared for

Ontario Ministry of Natural Resources, Toronto, March, 1974.

"Rough Road for Sand and Gravel?" The Financial Post. May 7, 1977.

Shelley, G.R. and Associates Ltd. Villeneuve Area Gravel Development and Reclamation Study. Report prepared for Alberta Environment, Edmonton, March, 1977.

Underwood McLellan and Associates Limited. Aggregate Resources of the Winnipeg Region. Report prepared for Manitoba Department of Mines, Winnipeg, Manitoba, June, 1976.

Government Statistics

Alberta Government, Bureau of Statistics. _Alberta Statistical Review Annual-1976_. Edmonton, Alberta, August, 1977.

Alberta Government, Municipal Affairs. _Population_. 1971-1977.

Alberta Government, Bureau of Statistics, "Population Projections for Alberta, 1976-2001", _Alberta Statistical Review_. 1976.

Statistics Canada. _Average Weekly Earnings -Unadjusted for Seasons_. Catalogue 72-002.

Statistics Canada. _Canadian Statistical Review_. Catalogue 11-003.

Statistics Canada. _Canada Year Book_. 1974.

Statistics Canada. _Construction in Canada_. Catalogue 64-201.

Statistics Canada. _Consumer Price Index_. Catalogue 62-001.

Statistics Canada. _Household Heads-Edmonton, 1971_.

Catalogue 93-707. Volume II-Part 1.

Statistics Canada. Housing Cost Index. Catalogue 62-010.

Statistics Canada. New Housing Construction Index. Catalogue 62-008.

Statistics Canada. New Housing Price Indexes. Catalogue 62-002.

Statistics Canada. 1971 Census of Canada. Households, Catalogue 93-702, Vol. II, Ottawa, May, 1973.

Statistics Canada. 1971 Census of Canada. Occupations, Catalogue 94-715, Vol. III, Ottawa, December, 1976.

Statistics Canada. Polulation by Years of Age for Census Metropolitan Areas. Catalogue 92-716, Vol. 1, Pt. 2, Apr. 1973.

Statistics Canada. Population-Winnipeg. Catalogue 92-806.

Maps and Planning Documents

County 12, Athabasca. Zoning Bylaw No. 10-197 Zoning Map. Prepared by Provincial Planning Branch, Athabasca, Sept. 30, 1975.

County of Beaver, No. 9. Bylaw #430. Prepared by Provincial Planning Branch, Ryley, Alberta.

Country of Camrose, No. 22. Zoning Bylaw No's. 223 (Zoning Map), 373, 403 and 467.

County of Lac Ste. Anne, No. 28. Ownership Map. Prepared by Torchinsky Consulting Ltd., Sangudo, Alberta, Jan., 1975.

County 30, Lamont. Zoning Bylaw No. 153. Prepared by the Provincial Planning Branch, Alberta Municipal Affairs, Lamont, July, 1974.

County of Leduc, No. 25. Ownership Map. Compiled by Stewart, Weir, Stewart, Watson, Heinrichs and Dixon. Leduc, Jan., 1977.

County of Parkland, No. 31. Ownership Map. Compiled and drawn by Public Works Department, County of Parkland, Stony Plain, Jan., 1977.

County of Ponoka, No. 3. Development Control Bylaw 5-70-DC. Resolution No. 5.

County of Strathcona, No. 28. Map. Compiled by Stewart et. al., Sherwood Park, July, 1976.

County 21, Two Hills. Zoning Map. Prepared by Provincial Planning Branch, Two Hills, July, 1974.

County of Wetaskiwin, No. 10. Development Control Bylaw, Map #1. Battle River Regional Planning Commission.

Municipal District of Sturgeon, No. 90. Ownership Map. Compiled by Stewart et. al., Morinville, Jan., 1977.

Municipal District of Westlock, No. 92. Zoning Bylaw No. 7-1973, Zoning Map. Prepared by Provincial Planning Branch, Westlock, Alberta, Aug. 1, 1973.

Questionnaires

City of Camrose

City of Edmonton

City of Wetaskiwin

County of Leduc

County of Smoky Lake

Province of Alberta

Statutes

The Clay and Marl Act. Revised Statutes of Alberta, 1970. ch. 50.

The Clean Air Act. Revised Statutes of Alberta, 1971. ch. 16.

The Clean Water Act. Revised Statutes of Alberta, 1971. ch. 17.

The Coal Mines Safety Act. Revised Statutes of Alberta, 1974. ch. 18.

The Department of the Environment Act. Revised Statutes of Alberta, 1971. ch. 24.

The Environment Council Act. Revised Statutes of Alberta, 1970. ch. 125.

The Land Surface Conservation and Reclamation Act. Revised Statutes of Alberta, 1973. ch. 34.

The Mines and Minerals Act. Revised Statutes of Alberta, 1970. ch. 238.

The Municipal Government Act. Revised Statutes of Alberta,

1970. ch. 240.

The Public Health Act. Revised Statutes of Alberta, 1970. ch. 294.

The Public Lands Act. Revised Statutes of Alberta, 1970. ch. 297.

The Public Lands Act. The Clay, Marl, Sand and Gravel Regulation 78/66. D.C. 297/66.

The Sand and Gravel Act. Revised Statutes of Alberta, 1970. ch. 328.

The Soil Conservation Act. Revised Statutes of Alberta, 1970. ch. 348.

The Surface Rights Act. Revised Statutes of Alberta, 1972. ch. 91.

The Water Resources Act. Revised Statutes of Alberta, 1970. ch. 388.

APPENDIX 1

PREDICTION METHODOLOGY

Households Data

The households data for past years which were used in the regression analyses, were derived from actual population figures. Figures on the numbers of persons per household, for the province and for the major urban areas, obtained from the five year Dominion census[40] were extrapolated to allow households figures for each year to be derived. Regional and provincial population data were obtained from Statistics Canada and the Alberta Department of Municipal Affairs.[41]

Future households data were derived from projections of population and persons per household. For the Central Alberta region, urban populations were projected on the basis of projections for the Edmonton sub-region to the year

2001, as supplied by the City of Edmonton Planning Branch.[42] Rural and sub-rural population were projected by examining the population growth of Federal enumeration areas composed entirely of rural or sub-rural household elements during the period 1966 to 1976 and reducing the growth rates, as indicated by Statistics Canada figures, to equivalent annual rates.[43] The rates for rural and sub-rural areas were then combined in their areal proportions to arrive at a single annual equivalent "rural" growth rate of 1.2 percent. Urban and rural population growths were then projected to give a total sub-region growth. The growth rates predicted for 2001 were extrapolated on to 2007 to complete the statistics for the study period. Provincial population projections were derived from Alberta Bureau of Statistics estimates.[44] Manitoba and Winnipeg populations were obtained from Statistics Canada and "Survey of Markets" sources.[45]

The "propensity" for members of each age group to form households was determined from detailed data derived from the 1971 Census[46], and that "propensity" was applied to projected future population age distributions to determine the persons per household expected annually until 2001 (with extrapolation to 2007). These data were found to obey a linear semi-logarithmic regression of past and future data. Therefore, a regression of the logarithm of actual past and projected future persons per household data was obtained with the following results:

For Alberta

Persons per household in year (I)

$$=3.099-0.1151*\log(I) \text{ where } I=1 \text{ in } 1978$$

Correlation Coefficient= -0.946

F Value= 34.063

For the Central Alberta Region

Persons per household in Year (I)

$$=3.154-0.0970*\log(I) \text{ where } I=1 \text{ in } 1978$$

Correlation Coefficient= -0.954

F Value= 20.176

Predicted persons per household data were applied to predicted populations to determine future households data.

Construction Spending

Construction spending on roadways in the study area by the Province and the City of Edmonton were determined directly from the records of those governments.[47] Spending by other urban areas and rural municipalities was determined by responses to questionnaires on municipal spending which were forwarded to the surrounding municipalities. Those responses along with Provincial and City of Edmonton data, were used to extrapolate the data from municipalities which did not reply or which did not provide sufficient data.

Spending on other construction was determined by using an arbitrary 17 percent of total road and building construction. The 17 percent figure was obtained, with relatively good agreement, from the Ontario and Manitoba studies and was resorted to because of a lack of regional data on that construction sector.[48] Regional building construction data, both residential and non-residential, was obtained from Statistics Canada records which, although excluding minor communities and municipalities, were relatively complete. Provincial building and engineering construction data for Alberta and Manitoba and building data for metropolitan Winnipeg were derived from Statistics Canada data.[49]

Construction spending data was reduced to a constant dollar basis by the application of road and building construction cost escalation indices and, in their absence, by use of Consumer Price Indices for the locality being considered.[50]

Regression Analysis

Once it was determined from examination that the Manitoba approach, of a regression model, might be practicable for application in this study, attempts were made to derive an appropriate prediction equation. In an effort to avoid the complications involved when the

projection of construction spending versus households was derived for the Province and then relegated to the study region portion of the province, regional data was used in the first case examined. All data was converted into constant 1976 dollar terms. The first attempt resulted in the following equation which was compared to the equation obtained in the Manitoba study:

For Edmonton

$$Y = -765109 + 7792.2 * (X)$$

Where:

Y= Total Construction spending in constant 1976 dollars (1000's)

X= Number of Central Alberta households (1000's)

Correlation Coefficient= 0.835

F= 6.907

t= 2.628

(Based on 5 years data: 1972-1976)

As derived in the UMA study:

For Manitoba

$$Y = -162394 + 2968.2 * (X)$$

Where:

Y= Total Construction spending in constant 1973 dollars (1000's)

X= Number of Manitoba households (1000's)

Correlation Coefficient= 0.876

F=29.570

(Based on 10 years data: 1964-1973)

The high slope coefficient derived for Central Alberta was felt to be a poor estimate, even providing some consideration for the difference in the absolute value of the 1973 versus 1976 dollars used in each case. It was therefore decided to investigate the situation further.

To determine the stability of the slope coefficient from time period to time period and from place to place, it was decided that residential and non-residential building data for Edmonton, for a longer time period, and from metropolitan Winnipeg and Manitoba would be examined. The results of these regressions are given in Tables 23, 24 and 25.

The conclusion was similar to that obtained in the Manitoba study, that attempts to forecast on the basis of one sector would not be successful. Slope coefficients for the two sectors considered were significantly different and coefficients for the same region were found to vary from time period to time period.

The above exercise was repeated for Edmonton and for Manitoba; using the change in households and the

TABLE 23

REGRESSION RESULTS - SET #1

Region and Time Period	Linear Regression Results For:			
	Residential Building versus Households		Residential and Non-Residential Building Versus Households	
	Slope Coefficient	Correlation Coefficient	Slope Coefficient	Correlation Coefficient
Edmonton				
1967-76	4542.5	0.804	---	---
Manitoba				
1963-72	2603.0	0.876	3824.1	0.916
1967-76	2720.1	0.708	1540.1	0.340
Winnipeg				
1963-72	3627.2	0.696	4329.8	0.712
1967-76	4438.5	0.447	1876.7	0.157

TABLE 24

REGRESSION RESULTS - SET #1

For Edmonton 1972-76:	Total Value of all Construction vs. Households	Road Construction vs. Households	Building Plus Road Construction vs. Households
Slope Coefficient	8146.4	326.0	7981.1
Correlation Coefficient	0.854	0.739	0.833

changes in households lagged one and two years as the independent variable. The "change in households" gave widely varying slope coefficients and lower and inconsistent correlation coefficients (-0.106 to -0.911). Lagging the change in households gave little or no improvement in the fit of the regression. Again, UMA's findings were confirmed, this time concerning the unsuitability of "change in households" as the independent variable.[51]

It was finally decided to abandon a model based entirely on the region and go to a provincially based regression curve. As well, the time periods considered for the regressions were increased where possible and segments

of those time periods examined separately. Constant dollar weekly wages were included in some regressions as an additional independent variable.[52] The results of this set of regressions are given in Table 25.

Both provincial and regional regressions based on sectors were again found to vary from time period to time period and from location to location.

The addition of real weekly wage did not provide any major improvement in the agreement between regions or between time periods. However, although the slope coefficient for Alberta data on total construction was not constant from period to period, it was decided that this instability was inherent in the processes generating the data and that the best approach would be to use the regression based on total construction spending for the Province of Alberta for the period 1953 to 1976 versus absolute numbers of households for the same period. The data from those figures was considered to be the best estimate of the curve that would result from the cyclical factors which influence construction spending from time period to time period.

Proportion of Spending Allocated to Central Alberta Region

This allocation was determined on a year by year

TABLE 25

REGRESSION RESULTS - SET #2

Regression	Alberta	Manitoba	Edmonton	Winnipeg
1. Residential Building vs. Households-20+Yrs.				
Slope Coefficient	3685.7	2946.2	1960.8	865.0
Correlation Coefficient	0.830	0.894	0.844	0.767
2. Residential Building vs. Households -10 Yrs., 1967-76				
Slope Coefficient	2117.4	2889.0	3441.4	1299.2
Correlation Coefficient	0.280	0.551	0.624	0.495

Table 25--Continued

Regression	Alberta	Manitoba	Edmonton	Winnipeg
3. Residential Building vs. Households -10 Yrs., 1957-66				
Slope Coefficient	1458.7	2252.0	-116.1	-24.3
Correlation Coefficient	0.586	0.797	-0.057	-0.018
4. Residential Building vs. Households -10 Yrs. from beginning of data series				
Slope Coefficient			1705.7	1761.8
Correlation Coefficient			0.607	0.657

Table 25--Continued

Regression	Alberta	Manitoba	Edmonton	Winnipeg
5. Residential Building vs. Households and Annual Average Weekly Wage -20+ Years				
Slope Coefficients				
Variable 2	3806.1	2633.9	-4174.0	-576.9
Variable 2	-29.0	33.4	252.3	188.3
Mu. Correlation Coefficient	0.830	0.894	0.872	0.820
6. Total Building vs. Households -20+ Years				
Slope Coefficient			3381.5	1587.6
Correlation Coefficient			0.930	0.833

Table 25--Continued

Regression	Alberta	Manitoba	Edmonton	Winnipeg
7. Total Building vs. Households and Annual Average Weekly Wage -20+ Years				
Slope Coefficient				
Variable 1			3527.6	610.7
Variable 2			-15.5	127.6
Mu. Correlation Coefficient			0.930	0.833
8. Total Construction -20+ Years				
Slope Coefficient	12080.7	8117.0		
Correlation Coefficient	0.969	0.849		
9. Total Construction vs. Households -10 Yrs. (1967-76)				
Slope Coefficient	11637.4			
Correlation Coefficient	0.910			

Table 25--Continued

Regression	Alberta	Manitoba	Edmonton	Winnipeg
10. Total Construction vs. Households -10 Yrs. (1957-66)				
Slope Coefficient	7590.2			
Correlation Coefficient	0.667			
11. Total Construction vs. Households -10 Yrs. (1950-59)				
Slope Coefficient	19855.1			
Correlation Coefficient	0.952			
Total Construction vs. Households and Annual Average Weekly Wage -20+ Years				
Slope Coefficients				
Variable 1	3169.1	18072.1		
Variable 2	2112.4	-1063.0		
Mu. Correlation Coefficient	0.952	0.870		

basis from the number of households in the study region as a proportion of the number of households in the province determined from population projections. Spending in the sub-region was allocated on this households basis because, with the large rural area included in the study region, the study region might be assumed to be a microcosm of the province in terms of construction spending in the same way as this was done in the Ontario study.

Spending in Each Sector

Data collected from suppliers (1976 only) and consumers (1972-1976) of aggregates in the Edmonton region and Statistics Canada were used to determine the proportion of spending which, historically, took place in the Central Alberta region in each sector.

Aggregate Input Factor

Aggregate input factors were derived from detailed analysis of data obtained from users of aggregate in the Edmonton region during the period, 1972 to 1976.

Types of Aggregate Used

The proportion of different aggregates produced by producers in 1976 and used in construction between 1972 and 1976 were used to determine the proportion of the different aggregate materials being used in the region.

Aggregate Reserves at 2007

Used in conjunction with reserves data contained in the "Edmonton Regional Aggregate Study", figures obtained for the aggregate usage anticipated to occur in the study region between 1978 and 2007 were used to determine the amount of existing reserves that will remain after that period of usage.

Effects of Zoning Regulations

The records of the Provincial Department of Municipal Affairs, the zoning regulations of rural municipalities where they existed, land use maps and plans and publications from the Edmonton Regional, Battle River and Red Deer Planning Commissions were used to determine the existing or planned land usage ascribed to locations where aggregate deposits are to be found.[53] The locations were then grouped

as to zones which may allow extraction operations for aggregate and those which it is apparent would not allow extraction activities and the reserves contained in each zone tabulated to determine extractable and non-extractable reserves.

APPENDIX 2

DEVELOPMENT OF ONTARIO AND MANITOBA MODELS

As indicated previously, both the Ontario and Manitoba models started with population projections which were then related to measures of economic activity. The Ontario model however, was based on a "capital stock formation concept of macro-economic analysis"[54] while the Manitoba study was based on an empirical relationship between population and macroeconomic spending on construction.

Ontario Model[55]

The basic purposes of the Ontario study were to predict future transportation patterns for aggregate and to facilitate the development of an appropriate land use

strategy.

The concept of the formation of capital stock used by Proctor and Redfern allows that "Out of annual Gross Provincial Product (GPP) a certain proportion goes into savings (S) which are the source of the annual flow of investment (I)." While not all investment funds generated in Ontario are invested in Ontario and not all funds invested in Ontario originate in Ontario, the study assumes that a relationship exists between GPP and investment:

I= Change in KF + Change in KV

Where:

KF= Fixed Capital Formation

KV= Variable Capital Formation

(in year t)

and

C= KF

Where:

C= Total Construction

While variable capital formation includes equipment and inventory formation, fixed capital includes building and engineering construction. KF then becomes a projection of total construction activity and where d is the proportion of GPP going into construction in year t; total construction is defined as:

$C = d * GPP$

Historical data on d was found to be fit by a modified exponential curve which tended to a bottom asymptote over time. GPP was defined as:

$GPP = Y * Pop$

Where:

Y= Per Capita Income

Pop= Population

(for a given year t)

Historical real income data for the years 1947 to 1976 were adjusted to constant employment and participation rates and found to be described by the following ordinary least squares regression derived time series:

$$\log \frac{y}{1000} = +0.4003 + 0.001(t) \quad (t=0 \text{ at } 1958)$$

Application of the d (proportion of GPP going into construction) to GPP derived from a population projection and the projection of real per capita income resulted in a figure for the value of construction. The population projection used for this model assumed a medium fertility rate and a net migration into the province of 70,000 per annum.

The Central Ontario Region's share of total provincial construction was then portioned out based on the fraction of the province's population resident in the region and the relative growth rates of the province and region.

While the proportion of construction in each of the residential, non-residential and engineering sectors was readily available for the province for a number of years back, the apportionment for the study region was based solely on 1972 data. The proportions data that was obtained is given in Table 26.

The residential sector is weighted more heavily in the smaller unit because of the greater residential component in the largely urban metropolitan Toronto region as opposed to the province as a whole. Also, since roadways are well developed in urban areas, engineering construction spending is reduced accordingly in an urban area.

The final step in arriving at a prediction of actual quantities of sand and gravel and crushed rock used in the Central Ontario Region was to multiply construction spending estimates by constant dollar based factors for tons of aggregate utilized per dollar of spending, based on an assessment of 1971 data.

Winnipeg Model[56]

The Winnipeg study included an area 6500 square miles

in size, extending approximately 40 miles south and north, 30 miles west and 45 miles east of Winnipeg. Its stated objective was "to provide qualitative and quantitative estimates of aggregate potentially available to support construction requirements in the Winnipeg Region over the long term."

As a result of perceived difficulties associated with using variables such as Gross Provincial Product, value added from manufacturing and personal income which are subject to uncertainties in future levels as well as valuation, the Winnipeg model was based on a simple regression of construction spending in Manitoba versus households. The testing leading to the derivation of the regression equation was described as follows:

> A regression model was fit to total construction value in Manitoba, population, population change, number of households, annual change in households, personal income and value added in manufacturing. In the same way, a similar analysis using only one independent variable was carried out. As the reduction of the equation to a simple relationship did not detract from the reliability of the results, the simple regression model was ultimately selected to forecast total construction spending. Of all the independent variables examined, the number of households was discovered to be the best single variable for predicting the level of construction activity in Manitoba--sufficient that the addition of other variables did little to improve the quality of the regression equation.[57]

The resultant regression equation was:

$$Y = -162{,}394 + 2968.2*(X)$$

Where:

Y=Total Construction spending (excluding residual items) in constant 1973 dollars (thousands)

X= Number of Manitoba Households (thousands)

The overall F statistic for the regression was 29.570, the coefficient of determination was 0.767.

Two Statistics Canada population projections were used to provide a base and an alternate forecast case for the regression. The base case was the preferred projection while the alternate case assumed high fertility and net outward migration giving a lower eventual population. Future numbers of households were projected using the proportions of household heads found in each age group during the 1971 Census in Manitoba. The proportions were multiplied times the future populations expected in each age group to determine the numbers of households by determining the projected number of household heads.

Sectoral allocations, for the province and region, and aggregate usage coefficients were determined by using a combination of Statistics Canada data and the data collected from aggregate producers and users, resulting in annual tonnages of the sand and gravel and crushed rock that would be required.

By all indications, the Manitoba study was an attempt

to improve on the Ontario study, however, basing the study's regression line on only 10 years of data could seriously harm its credibility given the wide variation in coefficients that occurs between subsequent periods of that time length.

TABLE 26

SECTORAL SHARES OF CONSTRUCTION SPENDING

IN ONTARIO - 1971

Sector	Geographic Area	
	Ontario	Central Ontario Planning Region
Residential	33%	45%
Non-Residential	35%	32%
Engineering	32%	23%

SOURCE: Proctor and Redfern Ltd., Mineral Aggregate Study Central Ontario Planning Region

APPENDIX 3

REGULATIONS AFFECTING THE AGGREGATE INDUSTRY

The following is a brief summary of regulations governing the extraction of sand and gravel as determined by a literature search and information obtained from local and provincial authorities.

1. Clay, Marl, Sand and Gravel Regulations[58]

(Clay and Marl Act, Sand and Gravel Act[59])

These regulations state that surface rights to minerals reside with the owner as long as they can be extracted by surface excavation. These Acts give the requirements for exploration licences, sand and gravel licences and leases and royalties with respect to extracting such minerals from Crown land. Development of Crown land

requires the submission of an operating and reclamation plan. Municipal authorities are given the authority to require development permits for production from privately owned lands.

2. Clean Air Act[60]

The Clean Air Act makes provisions for the granting of construction permits, operating licenses and alteration permits for plants, such as gravel crushers and asphalt plants, which may introduce contaminants into the air. Powers of control and prosecution are given to the Province.

3. Clean Water Act[61]

This Act governs the issuance of permits to use water in manufacturing processes. To obtain permits allowing construction and licenses for operations, the prospective user must submit information regarding the source of the water; the amount taken in, used and discharged. Information is also required regarding the nature and quantities of any contaminants which may be discharged into the water. The government is given the power to control effluent discharge and to take legal action.

4. Coal Mines Safety Act[62]

This Act applies to every mine site, mine and processing plant in Alberta. It is meant to ensure the use of safe practices and the protection of the health of employees. It makes stipulations regarding the qualifications and duties of employees and the safety standards which surface and subsurface facilities must meet.

5. Department of the Environment Act[63]

The Department of Environment was created by the Act and empowered to make regulations governing the conservation, management, utilization, control, and pollution of natural resources, the prevention and control of noise, the quality or quantities of natural resources and the disturbance, destruction, pollution or other adverse treatment of natural resources. The Department can establish Restricted Development or Water Conservation Areas and issue orders enforcing conformance to standards.

6. The Environment Council Act[64]

An Environmental Council of Alberta was created to review and investigate policies and programs respecting

environmental issues, including the conservation, management and utilization of natural resources, and to ensure conformance to the requirements of the Clean Air Act, Clean Water Act, the Department of the Environment Act and the Land Surface Conservation and Reclamation Act.

7. Land Surface Conservation and Reclamation Act[65]

This Act covers approval of development and reclamation plans for surface disturbances in respect of neighboring residential use, aesthetic or scenic issues, recreational pursuits, flora and fauna preservation, existing agricultural, commercial or industrial development, transmission and transportation facilities, housing and surface requirements; geotechnical exploration, water and groundwater management in relation to land conservation guidelines. Responsibility is given for the preparation and maintenance of an inventory of natural resources within Alberta.

8. Mines and Minerals Act[66]

The Mines and Minerals Act defines minerals and assigns jurisdiction over clay, marl, sand and gravel to

separate legislation.

9. Municipal Government Act[67]

Municipalities are allowed to acquire land for use as quarries, gravel or sand pits and to enter into agreements respecting the exploitation of aggregates. The Act also gives municipalities the right to pass by-laws regarding sanitation, subject to the Clean Water Act, and the operation of construction equipment on streets as well as ownership and control of highways within the municipalities.

10. Public Health Act[68]

The Public Health Act makes it possible to prescribe maximum limits for concentrations of contaminants released into water or air and to require the abatement of nuisances which may endanger health.

11. Public Lands Act[69]

This Act gives the Province authority to regulate and licence exploration for and the removal and disposition of clay, marl, sand and gravel on public lands.

12. Soil Conservation Act[70]

The Soil Conservation Act gives powers and authority to prevent soil deterioration on any lands in the province due to action of wind, water or any other causes.

13. Surface Rights Act[71]

This Act applies to all lands in Alberta. The Surface Rights Board is empowered to grant right of entry for the removal of minerals, construction of tank stations or other structures, construction of pipelines, power transmission and telephone lines as allowed under the terms of the Act.

14. Water Resources Act[72]

With respect to aggregate, this Act allows granting of permits for removal of aggregate from water bodies and the licensing of water use for gravel washing.

APPENDIX 4

PREDICTION PROGRAMS AND DATA

Copies of the computer programs and the data (in brackets) used to generate Projection #1 are presented in this section. The "Growth Rate Program" presented first was used to combine the annual projected population growth rates for the rural and urban segments of the study region population into one population growth rate.

The "Aggregate Usage Program" was used to project annual and cumulative aggregate usage in the study region for the years 1978 to 2007.

Growth Rate Program

```
Dimension U(30),V(30)
Read *,UP,CP
READ *,(U(I),I=1,30)
READ *,(V(I),I=1,30)
PRINT 120
DO 110 I=1,30
UP1=UP*(1+U(I))
CP1=CP*(1+V(I))
GR=(UP/(CP+UP))*U(I)+(CP/(CP+UP))*V(I)
PRINT 130,UP,UP1,U(I),CP,CP1,V(I),GR
UP=UP1
110 CP=CP1
STOP
120 FORMAT
(5X,'UP',6X,'UP+1',5X,'UGR',6X,'CP',5X,'CP+1',6X,
    'CGR',3X,'OVERALL G.R.')
130 FORMAT
(2X,I8,1X,I8,1X,F6.4,2X,I8,1X,I8,1X,F6.4,6X,F6.5)
END
```

WHERE:

UP= INITIAL (1977) URBAN POPULATION (604616)

CP= INITIAL (1977) RURAL POPULATION (154003)

U(I)= URBAN GROWTH RATE (.0244 X 4, .0218 X 5, .0191 X 5, .0169 X 5, .015 X 11)

V(I)= RURAL GROWTH RATE (.012 X 30)

GR= OVERALL STUDY AREA GROWTH RATE

UP1= UP, YEAR t+1

CP1= CP, YEAR t+1

Aggregate Usage Program

```
DIMENSION
R(30),Y(30),X(30),C2(30),D2(30),E2(30),RE(30),
     X1(30),GL(30)
100 READ(3,*) A,C,D,E,P,PE,H,O,S,C1,D1,E1
IF(A.EQ.0) GO TO 140
110 READ(3,*) B
IF(B.EQ.0) GO TO 100
120 READ(3,*) F,G,F1,G1
IF(F.EQ.0) GO TO 110
READ(3,*) (R(I),I=1,30),(RE(I),I=1,30),(GL(I),I=1,30)
PRINT 150
PRINT 160,A,B,C,D,E,C1,D1,E1,P,PE,H,O,S
T1=0
U1=0
V1=0
W1=0
PRINT 170
DO 130 I=1,30
Q=F+(G*GL(I))
Q1=F1+(G1*GL(I))
```

```
P=P*(1=R(I))
PE=(PE)*(1+RE(I))
X(I)=P/Q
X1(I)=PE/Q1
Y(I)=A+(B*X(I))
Y(I)=(440.41*X1(I)*Y(I))/X(I)
C2(I)=(C*C1*Y(I))/1000
D2(I)=(D*D1*Y(I))/1000
E2(I)=(E*E1*Y(I))/1000
T=C2(I)+D2(I)+E2(I)
U=H*T
V=O*T
W=S*T
T1=T1+T
U1=U1+U
V1=V1+V
W1=W1+W
PRINT 180,I,R(I),RE(I),T,U,V,W,T1,U1,V1,W1
IF(I.EQ.30) GO TO 120
130 CONTINUE
140 STOP
150 FORMAT
(6X,'1',5X,'2',8X,'3',5X,'4',5X,'5',5X,'6',7X,'7',
            6X,'8',5X,'9',5X,'10',5X,'11',4X,'12')
160 FORMAT
(3X,I8,1X,F7.1,1X,F5.3,1X,F5.3,1X,F5.3,1X,F6.4,1X,
```

```
              F6.4,1X,F6.4,1X,F8.3,1X,F7.3,1X,F5.3,1X,F5.3
170 FORMAT (2X,
'YR',4X,'GR',5X,'GRE',2X,'T.USE',5X,'SD',6X,

              'GR',6X,'CC',7X,'CT',7X,'CS',7X,'CG',7X,'CC'
180 FORMAT
(2X,I2,3X,F5.4,2X,F11.3,1X,F10.3,1X,F10.3.1X,F10.3,

              1X,F10.3,1X,F12.3,1X,F12.3,1X,F12.3,1X,F12.3
END
```

WHERE:

A= Constant, Dollars versus households regression (-1,610,490)

B= Slope coefficient, Dollars versus households regression (12080.7)

C= Proportion of construction dollars going into building construction (0.738)

C1= Input Coefficient - Tons of Aggregate used per dollar of building construction (0.0036)

C2= Tons of aggregate used in building construction

D= Proportion of construction dollars going into roadway construction (0.097)

D1= Input Coefficient - Tons of Aggregate used per dollar of roadway construction (0.0909)

D2= Tons of aggregate used in roadway construction

E= Proportion of construction dollars going into other construction (0.165)

E1= Input Coefficient- Tons of Aggregate used per dollar of other construction (0.0104)

E2= Tons of aggregate used in other construction

F= Constant, Persons per household versus time regression for Alberta (3.0991)

F1= Constant, Persons per household versus time regression for Central Alberta (3.154)

G= Slope coefficient, Persons per household versus time regression for Alberta (-0.1151)

G1= Slope coefficient, Persons per household versus time regression for Central Alberta (-0.0970)

GL(I)= Logarithm to base 10 of Year I

H= Proportion of all materials used that is made up by sand (0.117)

I= Year of prediction, where 1978=1

O= Proportion of all materials used that is made up by gravel (0.503)

P= Initial population of Alberta, 1977=1868.427 (1000's)

PE= Initial population of Central Alberta, 1977= 758.619 (1000's)

Q= Persons per household, Alberta in Year I

Q1= Persons per household, Central Alberta in Year I

R(I)= Alberta population growth rate in Year I (See Column 2, Table 10)

RE(I)= Central Alberta population growth rate in Year I (See Column 3, Table 10)

S= Proportion of all materials that is made up by quality material (0.380)

T= Total material used per annum

T1= Cumulative total material used per annum

U= Total sand used per annum

U1= Cumulative total sand used per annum

V= Total gravel used per annum

V1= Cumulative total gravel used per annum

W= Total quality aggregates used per annum

W1= Cumulative total quality aggregates used per annum

X(I)= Households in Alberta in Year I

X1(I)= Households in Central Alberta in Year I